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ABSTRACT

Abstracts of most of the papers, symposia, discussion groups, round tables, and poster sessions presented at the 64th conference of the National Association for Research in Science Teaching (NARST) are provided. Subject areas addressed are as follows: teacher knowledge, cognitive development, conceptual change, curriculum issues, reform in science education, scientists and science education, semantic networks, factors influencing learning, equity in science education, science activities, curriculum reform and the research agenda, role of technology, knowledge of prospective teachers, teachers and teacher preparation, reasoning and thinking, science textbooks, historical and philosophical perspectives, concept mapping, teacher beliefs, directions for research in physics education, preservice teachers, instructional technology, teacher beliefs, theoretical bases for research, theory of planned behavior, science laboratory, student assessment, classroom discourse, telecommunication, developing science curricula, problem solving, biology education, writing in science, research topics/methods/priorities, comparative studies, science/technology/society curricula, college science, teacher enhancement, college teaching, concept learning, process skills, professional development of science teachers, content knowledge, implementing activity-based learning, constructivism, research of graduate science education, epistemological theories, student perception and attitude, creative thinking, research methods, conceptions of prospective teachers, concept knowledge representation, and assessing lab skills. (KR)

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ABSTRACTS

OF

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Organized to improve science teaching–through research

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NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

National Association For Research
In Science Teaching

64th Annual NARST Conference

The Abbey at Lake Geneva, WI
April 7-10, 1991

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National Association For Research In Science Teaching

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ASSESSMENT AND INVESTIGATION OF PRACTICAL PERFORMANCE IN SCIENCE CLASSROOMS

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During the early and mid 1980s, Australia and the United States participated in the Second International Science Study (SISS) conducted by the International Association for the Evaluation of Educational Achievement (IEA) which assessed science achievement across 17 countries. The IEA tested the achievement of children ages 10, 14, and 17 in 10,000 schools throughout these countries and concluded that in comparison to the other countries in the sample, Australia had slipped dramatically since the last test were carried out in 1970. In 1970 Australia ranked third in the 17 country sample; in the most recent testing Australia had slipped to tenth position. Practical activities in a laboratory-type environment have been traditionally an important feature of science instruction. The tradition was highlighted during the curriculum reform movements of the sixties and seventies when the newly developed curricula featured practical work as an essential means for learning and teaching science. The assessment of practical laboratory performance has been done with both pencil-and-paper tests and practical tests. However, due to time and equipment constraints, pencil-and-paper tests have tended to dominate practical assessment. Although long recognized as important, the assessment of practical skills was only a minor part of the First International Study. An optional part of the Second International Science Study was process skill testing of science practical skills for students at grade 5 and grade 9 level. Australia did not participate in this phase of the study. Six countries administered science practical skills test to students at these two grade levels. These countries were Hungary, Israel, Japan, Korea, Singapore, and the U.S.A. Science teaching at the primary and secondary levels in Australian schools claims strong emphasis on science processes and skills rather than on science content. In light of this, the investigators administered an Australian version of the internationally developed science practical test (for the first time in Australia) to a sample of Western Australian schools. The process skills tests administered in this Western Australian study were developed from the items and materials developed for the Second International Science Study (SISS). The Australian data was collected in the fall of 1989 by a team of two United States and two Australian science educators in the metropolitan area of Perth, Western Australia. Eleven Schools, both public and private, participated providing a sample of grade 5 and grade 9 students. The resulting data base was analyzed in three parts: overall performance levels for the various grade levels, comparisons being made with achievement test results; qualitative information about the specific strengths and weaknesses of students' practical skill performance; quantitative information about relationships between process outcomes and various predictors such as gender, home environment, classroom environment, etc. The resulting data revealed that students at both levels were reasonably successful at tasks requiring manipulative skills, but less successful at investigating and reasoning skills.

SCIENCE TEACHING AND TEACHERS' KNOWLEDGE: PROSPECTS FOR REFORM OF ELEMENTARY CLASSROOMS

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On both sides of the Pacific there has been considerable debate surrounding the state of elementary science teaching. In Australia and North America, there have been a number of reports on the parlous state of elementary science and the lack of impact of efforts to improve this situation. In the past the failure of such efforts tended to be explained in terms of teacher failure, poor implementation and lack of conditions for change. An alternative view, argued in this paper, is that teacher change is fundamentally connected to the knowledge teachers have and use. By this view it is only through a recognition of teachers' own social constructions of reality and the characteristics of teachers' knowledge that teacher change can be understood. This approach, it is argued, allows for ways of examining and explaining the current state of elementary teaching which are more connected with teachers' work and are more likely to suggest ways of establishing conditions for change. This paper draws on data from two longer studies of teaching in Canadian elementary schools. One was a five month examination of the work of five teachers as they participated in a school board sponsored program on interactive science teaching. The second study examined, over a period of eight months, the work of two teachers and their attempts to teach science. A participant observation methodology was used to compile field notes and unstructured interview transcripts. Close examination of the work of the seven teachers over an extended period led to some observations about the place of science teaching in the milieu of the elementary classroom. Further, it allowed for an understanding of the nature of teachers' work and the mechanisms of teacher change. The efforts of the study teachers to teach science were, at times, overwhelmed by the routine workload of the elementary school. Much of this routine was accepted by the teachers as part of the duties of being a teacher. As a consequence, the amount of time that teachers were actually able to invest into improving their science teaching (or any other part of their practice) was very small compared to the totality of their professional activity. Even if there were no other factors in the elementary science equation, this powerful contextual factor explains much about the limited impact of efforts to improve elementary science. A teacher's knowledge and therefore a teacher's work, it was found, was deeply rooted in a person's biography. Teachers' searches for a comfortable set of practices of science teaching reveals much about the tacit, biographical and practical qualities of teachers' knowledge. In turn, this explains much about the uncertain state of elementary science and sets the promise of reform in more realistic terms. Growth in teachers' knowledge about teaching science takes place in the intimate environment in which teachers find support to fine tune their practice and incorporate new ideas.

PROBING AND MAPPING SCIENCE EDUCATION AWARENESS FOR AN ENTIRE STATE

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The purpose of this study was to probe and map science education awareness in the state of Louisiana. In the spring of 1990, a random sample of 354 public secondary science teachers received a questionnaire which was designed to probe how well-informed the teachers were, using nine key indicators of science education awareness. (The sample was drawn after consultation with the Louisiana State Department of Education.) After intensive follow-up efforts, the final response rate was raised to 90.4% and every parish in the state was represented in the data set. Findings were reported using computer-generated graphics that show awareness patterns across ten regions of the state for each of the three key areas of science education which were investigated. (The regions are those used by the Louisiana Science and Engineering Fair and are geographic clusters based upon population centers.) A composite map, prepared by combining selected "key area" responses, summarizes the science education awareness of Louisiana's secondary science teachers. Findings are analyzed on the basis of related research. The approach used in this investigation should be of interest to any researcher who wishes to conduct a study of knowledge dissemination patterns for science teachers in his/her state.

PERFORMANCE-BASED ASSESSMENT OF BIOLOGY TEACHERS: PROMISES AND PITFALLS

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Growing dissatisfaction with existing modes of assessment that do not have high face validity has launched a movement into other modes of assessment (Shulman, 1988; Wiggins, 1989). This paper reports on research that explored the feasibility of performance-based assessments to evaluate high school biology teachers. Three modes of performance-based assessment were employed: portfolios, portfolio-based simulations, and independent simulations. Portfolios required teachers to collect and display evidence on how they performed three critical tasks -- planning, instruction, and evaluation. Portfolio-based simulations were designed to combine the contextual element of the portfolios with the standardization of simulations. For example, teachers were required to critique their own plans. Independent simulations were adapted from other disciplines and included the requirement to critique the videotape of another teacher. Five university researchers and four high school teachers comprised the design team; seventeen high school biology teachers completed eleven assessment activities during the 1988-89 academic year and the summer of 1989; sixteen teachers, education researchers and biologists, rated the performances using a holistic scoring procedure and group deliberation. The findings can be grouped into five categories. (1) Feasibility - teachers were able to do all of the assessment activities, raters were able to score them, and the activities did discriminate between teachers. (2) Differences in Ratings - some activities, such as the student evaluation activity, produced a wider range of ratings than others, such as commenting on instruction not based on a textbook. (3) Differences in performance - there were two characteristics of the materials of the teachers who consistently were rated higher, students focus and clarity. (4) Teachers Reactions - the teachers felt that completing the activities challenged their knowledge and skill and improved their practice of teaching. (5) Design Team Reactions - the design prepared a reviewed activity and made recommendations for future adaptations. For example, the computer exercises included too many tasks in a limited time period. Relying on a framework derived from the work of Haertel (1990) and of Wolf (in press) and examples from the research reported, the paper closes by illustrating potentials and pitfalls of performance-based assessments to those who are considering using them.

COGNITIVE DEVELOPMENT AND CODING ORIENTATION TO MEANINGS: A STUDY OF THE INFLUENCE OF THE SOCIAL CONTEXT ON THE STUDENTS' LEVEL OF COGNITIVE DEVELOPMENT

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In measuring students' Piagetian level of cognitive development, the influence of the social context, both at home and at school, has not been systematically explored, although there are already studies looking at the influence of cultural environments on the age at which children achieve a certain cognitive level. The study presented in this paper intends to give a contribution for a better understanding of how a child's cognitive level is determined and changed and also of its relation to achievement at school. Contrary to the most common trend, mostly psychological, this research has a sociological basis which seems to provide a sound ground for that understanding. Bernstein's theory in the sociology of education constituted the main theoretical framework. A number of crucial sociological variables (social class, gender, race, age, pedagogic practice, achievement) were studied and analyzed in terms of their relation to the cognitive level. The coding orientation, primarily determined by the family socialization (but that can be changed by other contexts, namely the school) was also studied. The sample is constituted by 76 students of the 5th/6th years of schooling (10.12 years of age) separated in three sets, each of which was submitted to pedagogic practices differing in terms of power (classification) and control (framing). The classes were all socially heterogeneous and with a similar composition in terms of social class, race and gender. Achievement was higher when the cognitive level was higher and this could be especially noticed in the competencies requiring a high level of abstraction. A relationship was also found with the kind of pedagogic practice students were submitted - the weaker the framing in the classroom's interaction, i.e. the greater the degree of control acquires had on their acquisition, the higher the cognitive level.

There was a relation with social class, children at the bottom of the social class scale having the lowest cognitive levels. Some relation could also be found with race in favor of white children. The cognitive level was related to age 11 years old showed, in general a higher cognitive level. There was found that a strong relation existed between the orientation to meanings and the level of cognitive development showed by students. On the basis of these results it can be said that this study gives some contribution to understanding of how a child's cognitive level is determined and changed. A possible causal relationship would be the social class and race influencing the cognitive level. Primary socialization at home leads children to develop a coding orientation to more abstract and explicit or to more concrete and implicit meanings (theory and empirical work can support this statement). These differential orientations to meanings may lead to differential levels of cognitive development and to differential levels of achievement especially in those competencies which require a high level of abstraction.

HYPOTHETICO-DEDUCTIVE REASONING AND MATURATION OF THE PREFRONTAL CORTEX

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Elementary school children in grades K, 1, 2, 4 and 6 were individually administered a series of seven increasingly difficult concept acquisition tasks that required use of a "if ... and ... then ... therefore" hypothetico-deductive reasoning pattern. If during administration of the tasks, the subject was unsuccessful, the experimenter attempted to explain how to solve the tasks. Performance on subsequent tasks was, therefore, a measure of the success of this minimal verbal training. Results of the study were striking as none of the 30 kindergarten children were successful while virtually all of the second grade and older children were successful. Evidence suggests that the abrupt acquisition of the ability to use the hypothetico-deductive reasoning pattern with descriptive problems of the sort used in this study is tied to maturation of the prefrontal cortex. Additional evidence suggests that, although the pattern of hypothetico-deductive reasoning can be applied by infants as young as 18 months of age, its range of applicability varies considerably across age.

TEACHING ALGORITHMIC PROBLEM SOLVING OR CONCEPTUAL UNDERSTANDING: ROLE OF DEVELOPMENTAL LEVEL, MENTAL CAPACITY, AND COGNITIVE STYLE

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It has been shown previously that many students solve chemistry problems using only algorithmic strategies and do not understand the chemical concepts on which the problems are based. It is plausible to suggest that if the information is presented in differing formats the cognitive demand of a problem changes. The main objective of this study is to investigate the degree to which cognitive variables, such as developmental level, mental capacity, and disembedding ability explain students performance on problems which: a) could be addressed by algorithms or b) require conceptual understanding. All conceptual problems used in this study were based on a figurative format. The results obtained show that in all four problems requiring algorithmic strategies, developmental level of the students is the best predictor of success. This could be attributed to the fact that these are basically computational problems, requiring mathematical transformations. Although all three problems requiring conceptual understanding had an important aspect in common (the figurative format), yet in all three the best predictor of success is a different cognitive variable. It was concluded that: a) the ability to solve computational problems (based on algorithms) is not the major factor in predicting success in solving problems that require conceptual understanding; b) solving problems based on algorithmic strategies requires formal operational reasoning to a certain degree; c) student difficulty in solving problems that require conceptual understanding could be attributed to different cognitive variables.

CONCEPTUAL CHANGE IN CHEMISTRY THROUGH COOPERATIVE PROBLEM SOLVING

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This study was designed to determine whether there was a difference in the attainment of conceptual change between chemistry students participating in small group cooperative problem solving strategy and those students participating in individual problem solving strategy. In order to do this the investigator developed a diagnostic tool called "Mole concept test" (MCT) to examine students' misconceptions in mole concept both prior to and following experimentation. This study used the pretest-treatment posttest control group design in order to study the main effects of treatment on conceptual change. The misconception as defined in this study refers to the preconceptions that the students might have, irrespective of their source, in a particular topic, which is unacceptable by the scientific community. This was measured by the MCT. The study consisted of four intact laboratory classes of freshmen college students (N=84) enrolled in General Chemistry - course in fall 1989. The conceptual change strategy incorporating small group cooperative problem solving treatment was randomly assigned to two of the four classes. The remaining classes were presented with individual problem solving strategy. The cooperative groups were formed heterogeneously, based upon the student's performance in the pretest. The dependent variable was measured by the posttest scores on MCT. An analysis of covariance was performed to analyze the post-test data holding the pretest scores as the covariate. Student discussion in cooperative groups were recorded and quantified as behaviors suggestive of impeding or promoting conceptual change. Characteristics of successful and unsuccessful conceptual change strategies were determined through an analysis of the transcripts of the audio-tapes, students' written works and classroom observations. Qualitative analysis of the group discussion was also attempted. A coding system developed by Basili (1989) was used for these purposes. The results of this six-week study indicate that the attainment of conceptual change in cooperative problem solving students is significantly higher than that in the individual problem solving students. There was also a significant difference in the type of verbal behavior pattern that took place in the cooperative groups that were successful in achieving conceptual changes as opposed to those that were unsuccessful in doing so. There was more evidence of occurrence of "promoting" behaviors in successful groups than in the unsuccessful groups. Thus it was concluded that the type of verbal behavior pattern that takes place within cooperative groups determines whether conceptual change will take place or not. It was also evident from the data that there was a greater occurrence of "promoting" behavior in the cooperative group student-interaction than in the individual student-interaction. Hence it was concluded that carefully planned and supervised cooperative problem solving strategy was more effective in achieving conceptual change than the individual problem solving strategy.

CONCEPTUAL CHANGE IN INTRODUCTORY PHYSICS STUDENTS

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It is well known that common sense beliefs about motion, which result in misconceptions, are very resilient. Conventional physics instructions do very little to modify those ideas. The present study compared the effectiveness of a non-traditional method of instruction with the conventional mode of teaching in an introductory college level physics laboratory course. The nontraditional method, called the Socratic-Dialogue-Including (SDI) method involved discussion, drawing freebody diagrams, and interactive engagements of students in the laboratory. For the first six weeks of the semester two of the six laboratory sections were taught by the SDI method and the other four sections, the comparison group, were taught by the traditional method. The differences in the teaching-learning situation under the two modes of conducting the laboratory experiences of the students were established in two ways: 1) by analyzing the responses of the students on a Perception of Treatment Scale; 2) by examining the perception of independent observers making observations on both type of laboratory sections. There was a significant difference between the perception of the students from the SDI and the standard laboratory sections. All the observers perceived the mode of instruction to be clearly different under the two methods. Assessment of concepts held by the students was performed by comparing 1) the pre- and post-course mechanics test scores; and 2) the performance on the demonstration interviews. In addition, students' science anxiety and their attitude toward science laboratory before and after the study were also assessed. There was no significant difference between the two groups on their science anxiety level and their attitude toward science laboratory. These findings were not surprising since attitudes are dispositions acquired over time. A significant difference was found between the two groups on the Mechanical Diagnostic Test scores and the concept scores obtained from the interview transcripts. This indicates that modification of naive knowledge toward a scientific one needs a non-traditional approach that challenges the existing conceptual frameworks of the students and offers them a more plausible explanation of their experiences.

THE EFFECTS OF CONCEPTUAL CHANGE METHODS COURSE ON PRESERVICE ELEMENTARY TEACHERS' CONCEPTIONS ABOUT SCIENCE CONTENT AND PEDAGOGY

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Recent research in science education has indicated that students frequently have poor conceptions of science. However, science instruction used by most elementary teachers does not provide experience that promotes conceptual change. It would be desirable to design teacher education courses that prepare prospective teachers for this type of teaching. The objectives of this research were to describe a course designed to change the conceptions elementary teacher candidates have about science content and pedagogy, compare the effects this course has on students' understanding of content with students enrolled in traditional and inquiry-oriented methods courses, and describe the effects of the conceptual change course on students' perceptions of science pedagogy. Studies such as this one can be used to help develop science teacher education courses which facilitate change in teacher candidates' scientific content and pedagogical knowledge. A five step approach was designed from research on conceptual change to replace students' naive conceptions with scientifically accepted concepts. This approach was used to teach content about the water cycle to elementary teacher candidates. Students enrolled in traditional and inquiry-oriented science courses were compared to this conceptual change group. After the content intervention, the conceptual change group was taught how to use the techniques and practice taught lessons they created to elementary students in their field placements. The subjects were pretested about the water cycle, using an exam with 14 open-ended application questions. The subjects were posttested immediately following the three week intervention, and five weeks following the posttest. A two-way ANOVA was performed on the science content test data. A Tukey post-hoc analysis was performed to determine where interaction effects occurred. Significant differences were found in the test scores for type of treatment, test and for the interaction. The traditional and inquiry-oriented groups had no significant change in average number of correct conceptions. The conceptual change group, however, did have significant change. These results suggest that conceptual change teaching can be more effective at improving teacher candidates' conceptual understandings than either traditional or inquiry-oriented methods. A subgroup of students in the conceptual change group were interviewed prior to and after the course about their views of science pedagogy. All students in the subgroup were able to successfully write conceptual change lessons about the water cycle and teach them in their field placements. Interview data suggest that these students shifted their science teaching views from traditional orientations toward those used in the course. All students stated they would "definitely use" the conceptual change model in their future science teaching.

NATIONAL SCIENCE CURRICULUM AND PROFESSIONAL CONFLICT

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There are various forces of influence or interplay with which science teachers must contend. These forces include the processes through which educational policies and programs are developed, the way science curriculum is used in the classroom, and a teacher's autonomy for decision-making when dealing with these issues. In making teaching decisions, science teachers must somehow deal with issues in ways that are contrary to their views about teaching and learning. Thus the amount of latitude a teacher has in dealing with these issues is an important point to consider. This study reports how decisions about a national science curriculum that science teachers of Costa Rica make may be in contrast to how they view the fit between what they are teaching and the needs of students. These conflicts resulted in three types of science teachers' responses: (1) teachers who acquiesced to the demands of the national science program; (2) teachers who tried to find ways to resolve the conflict between national curriculum and their obligations to their students; and (3) those who chose not to forfeit their own beliefs to the demands of the national science curriculum and left the profession.

CURRICULUM DEVELOPMENT IN ANIMAL SCIENCE: A UNIVERSITY, ZOO, AND SCHOOL DISTRICT COLLABORATION

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This paper reports the results of a two-year collaborative project, funded by the National Science Foundation, to develop and implement curriculum units in animal science for elementary and middle school science instruction. Collaborators included a science education professor, a biology professor, a school district science specialist, a zoo curator of education, and a group of elementary and middle school teachers of science. The common objective of the curriculum units were using the zoo as a resource in teaching science, increasing the emphasis on scientific method in science instruction, providing more active learning experience for students, heightening student awareness of ecological threats to endangered species, and increasing student motivation. The project aimed to persuade the teachers to internalize these objectives in their own teaching. Qualitative and quantitative research methods were used to ascertain how well the project succeeded. The study demonstrates that collaborative curriculum development can result in creative ideas about how to use community resources to improve school instruction. Furthermore, it can generate commitment to faithful implementation of new curricula. The study also confirms the improvement in student response to learning science when there are increased opportunities for active learning. The kinds of collaborative activity included in the present project can therefore be confidently recommended to other universities, school districts, and zoos (or community educational resources) interested in such partnerships.

COMBINING CURRICULUM AND PROFESSIONAL DEVELOPMENT CAN MAKE A DIFFERENCE: SCIENCE TEACHING IN NEW BRUNSWICK AND NOVA SCOTIA GRADES 7, 8, AND 9

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The results of a survey of New Brunswick and Nova Scotia grades 7, 8, and 9 science teachers affirm that a project that links curriculum and professional development can have a significant impact on instructional practices. This is so even when other circumstances are not so propitious for the improvement of teaching. The Atlantic Science Curriculum Project (ASCP) developed textbook resources for both students and teachers through extensive teacher participation in planning, writing and field testing. The resulting materials facilitate a constructivist pedagogy and provide students' contexts for learning which link science with technology, society and the environment. The introduction of these materials into schools in Nova Scotia and New Brunswick has been found to be associated with major changes in teaching practices. The survey results indicate that significant further improvement in teaching practices could likely be achieved through improvement of the not so propitious conditions in which many science teachers teach (such as poor location for much of science teaching, teaching assignments which in about half the cases include the teaching of other subject area most of the time and consequent lack of affiliation/participation of many teachers in voluntary professional development activity in science. The analysis of the survey data included the comparison of teacher responses to questions about teaching circumstances with their responses to questions about teaching practices. Relative to the practices of teachers who are not yet using SciencePlus, the textbook resource developed by the ASCP, users of this resource conduct practical activities more frequently (on average, about twice as frequently) and give greater emphasis to assessing students for understanding rather than recall. Indeed, three-quarters of the users report that half, most of all of their test questions examine for understanding, whereas 60% of the non-users report testing predominantly for recall. Chi-square statistics were computed for the cross tabulations with the following results for the two relationships, respectively: chi-square = 40.26923, P = .0000; and chi-square - 63.78030, P = .0000. The longer the association with the materials, including the period of their development prior to publication, the more likely it is that a teacher will conduct practical activities frequently and assess students for understanding rather than recall. Most of the change, however, takes place during the first year when the published material is available; therefore, professional development alone, even when associated with curriculum development, is not likely to have the kind of result that can be achieved when this process leads to the use of published material for both students and teachers.

REFORM IN SCIENCE EDUCATION: ASSUMPTIONS AND ALTERNATIVE VIEWS

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The purpose of this panel discussion is to identify and discuss assumptions implicit in recent reform proposals and suggest alternative views of education, particularly science education, which we believe better address the needs of a pluralistic society. The first paper addresses assumptions about the nature of knowledge and learning and draws on the philosophy, history, and sociology of science as well as constructivist views of knowing and learning to challenge assumptions that a focus on content knowledge and achievement alone promote greater learning. The second paper identifies the need for a multicultural education in American public schools and identifies competencies needed by multicultural science teachers. The third paper examines gender issues in science education including the omission of women scientists from presentations of the history of science, the presentation of science as embodying stereotypical masculine attributes, and approaches to science teaching which emphasize objectivity and competition at the expense of subjectivity and collaboration resulting in the alienation of many students from science. The fourth paper examines the goals of the reform proposals, compares and contrasts these goals with the goals of the science education community and suggests alternative goals to address the needs of female and minority students.

VOLUNTEERS IN THE SCIENCE CLASSROOM: A STUDY OF THE BENEFITS, PROBLEMS, AND ISSUES

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Multiple-site educational programs are usually expected to accelerate implementation and potential impact while at the same time providing an opportunity to examine the effect of various contexts on the activity. Such an arrangement can present problems for both external researchers/evaluators and the site staff when attempting to study the multi-site activity. Educational activities at each site may be linked by a central philosophy, goals, or cluster of objectives; however, the funding agent may encourage each site to individualize it's approach. If the sites are widely separated or have limited interaction, variation can be quite pronounced. The National School Volunteer Project (NSVP) exemplifies this situation and provides the focus for the research study. The research investigates the implementation and use of volunteers, in science, mathematics and technology in the classroom, and identifies the perceived benefits of volunteer interaction from the level of students, teachers, administrators, site coordinators, and the volunteers themselves. It also reflects the researchers perspectives of the advantages and disadvantages of multiple-site studies.

SCIENTIST AND ELEMENTARY TEACHERS: PARTNERS IN SCIENCE TEACHING

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The Science Alliance -- a coalition of industry, business, and education in a mid Atlantic state -- developed and sponsored a partnership project to help elementary teachers overcome obstacles to teaching quality science. Teachers were provided with training and equipment to teach an activity-based unit and one group was paired with scientists to implement the unit. The intent of the Scientist and Teacher Partnership Project was to bring together the scientific expertise of scientist with the classroom expertise of teachers to help both become more confident and skilled at teaching elementary science. This paper describes the project and examines the responses of the participants to determine whether they perceived partnerships to be feasible and effective. Twenty fourth, fifth, and sixth grade teachers were selected for the project. All received six hours of training and equipment to teach a SAVI/SELPH unit. Twelve of the teachers, the experimental group, were paired with scientists. These teacher-scientist partners then team taught the unit to the teacher's class. The other eight teachers, the control group, taught the unit on their own. Eleven scientist volunteers participated in the project. Their training consisted of a two hour seminar in which they learned about pedagogy, classroom management, and children's thinking about science concepts. They also attended the second SAVI/SELPH workshop with their partners to learn about the unit and set up the team teaching experience. Evaluation procedures included: journals kept by scientists and teachers during the teaching experience; an evaluation conference attended by the participants; and end-of-the unit questionnaires completed by scientists, teachers, and students. The experimental group responses were very positive. The scientist volunteers rated the overall project "5": "excellent." They cited the training, preparedness of the teachers, the division of labor between themselves and their partners, and the positive response from the students. The experimental group teachers gave a mean rating of 4.9 to the project. They were very pleased with the training, equipment, and contributions made by their scientist partners. Only one team reported that their partnership did not work. The control group teachers were generally pleased with the project because they received equipment and training. Most indicated that they would like to have the opportunity to work with a scientist in a similar project. The groups' mean rating of the project was 4.7 The elementary students were quite pleased with the project regardless of whether they were in the control or experimental group. They especially liked "doing the experiments" and those in the experimental group found the scientist to be helpful. The overall project rating mean for the students in both groups was 4.1 to 4.6. Thus, scientist and teacher partnerships show promise as an effective way to help elementary teachers teach activity-based lessons and scientists feel comfortable in the elementary classroom. But providing training and equipment and assistance in establishing partnerships is an essential part of such a project.

AN ANALYSIS OF THE EFFECTIVENESS OF AN INTERDISCIPLINARY POSTER-NEWSLETTER IN IMPROVING COMMUNICATION BETWEEN UNIVERSITY SCIENTIST AND SCIENCE EDUCATORS

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This research paper describes the development of a unique poster-newsletter called Science Talk and analyzes its effectiveness at a major research university. The newsletter was developed to make information regarding upcoming research seminars sponsored by the science departments available campuswide and to raise the scientists' awareness level regarding the University's science education program. The first section of this research paper provides the context of the analysis--offering an overview that explains the development and distribution of the newsletter. The second part of the paper describes measures used to evaluate the effectiveness of the newsletter. A readership questionnaire was attached to 150 copies of Science Talk and they were distributed to a stratified sample consisting of three groups. All the heads of university science units received a questionnaire as did a random sample of both graduate students and professors in the sciences. The forms were coded to allow identification of the respondent as an administrator, a professor, or a graduate student. The questions were framed using either a multiple-choice or a Likert scale (5-point continuum), and space was provided both for comments on specific questions and for general comments. Questionnaire items dealt with personal preferences for different types of information included in Science Talk, awareness levels regarding science education topics, and attitudes toward science teaching. Methods of analysis differed for each question, depending on the type of data collected. The responses to each question were analyzed separately for each group - administrators, professors, and graduate students. Intergroup differences between administrators, professors, and graduate students were found, and the nature of the differences was explored. The section of Science Talk most frequently read first by all groups was the seminar schedule. All groups did make use of the information Science Talk provided. Although all groups reported that they became more aware of research activity outside of their own department; the effect on graduate students was greatest. In addition, all groups demonstrated that their awareness of the science education program had increased. The consensus of each group was that good science teaching is not valued at the university level. In addition to the questionnaire, several other sets of information were used for triangulation in evaluating effectiveness. The newsletter was seen to be conspicuously posted in the science buildings on campus during a hall-and-office survey. Anecdotal information concerning the usefulness of the newsletter was received from graduate students, professors, and several upper-level administrators including the chancellor of the University. This research shows that poster-newsletters, such as Science Talk, can be very effective in exchanging information vital to both scientists and science educators.

PEDAGOGICAL CONTENT KNOWLEDGE: DEFINITIONS AND IMPLICATIONS FOR SCIENCE TEACHER EDUCATION AND RESEARCH

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Past attempts at elucidating the knowledge base of the effective teacher across both teaching context and subject matter specialization have provided researchers with little fruitful information. Recognizing this, Lee Shulman called for a new paradigm in educational research which aims at understanding the relationship between teachers' cognitive understanding of subject matter and classroom instruction within specific learning situations. This paradigm emphasizes the importance of elucidating at least three major categories of teacher knowledge: subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge (PCK). Whereas subject matter knowledge is described as being the knowledge of the content specialist and pedagogical knowledge that of the general pedagogue, PCK is proposed to exist as the distinctive body of knowledge of the content teacher. In general, PCK consists of the techniques teachers use to represent subject matter in order to make it comprehensible to students. The reification of PCK has sparked research efforts across subject matter specialization in the field of education, including science education. However, Shulman's vague definition of PCK has resulted in a constellation of research methodologies and interpretations among researchers, some of which exist in contradiction to one another. The purpose of this symposium is to clarify the definition of PCK and to explore its implications for science teacher education and research. Four varied statements will be made by the presenters in this session, all active researchers in the area of PCK and teachers' knowledge about science. The first presentation will define PCK as a unique knowledge domain which develops from an integration of several other domains of teacher knowledge. The second statement will challenge the premise that PCK exists as a separate domain of knowledge. The inability of many preservice and inservice teachers to transfer generic educational skills to the classroom will be addressed. The third presentation will advocate a deemphasis of PCK. This symposium will act as a first step toward reaching a common understand of PCK, and will provide a focus to future research attempts in this area.

SEMNET IN THE CLASSROOM

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The SemNet software is a Macintosh program for constructing systematic knowledge representations in the form of semantic networks. SemNet was designed primarily to help students focus their attention on weaving individual pieces of knowledge together to construct an integrated, cohesive, meaningful whole. However, the needs of instructors and researchers have also been considered, particularly as a tool for organizing their own knowledge and studying students' knowledge. This paper set discusses SemNet's use in several college-level classrooms for preservice elementary science education programs to facilitate teacher and student knowledge reconstruction. Preservice teachers enrolled in three science courses were asked to represent their content knowledge in a semantic network, while organizing the content for course design. Networks on content areas and also on teaching, learning, and curriculum development concepts were also built by both the course instructors and students. These were used for presentation during instruction and for browsing as a study tool. The perceived value of SemNet as an instructional vehicle was assessed for teachers' comments. Student generated SemNet maps were evaluated according to numbers of concepts, relations, and instances. Preservice teachers' ability to plan curriculum through sequencing of science concepts, instructional strategies and learning outcomes in their SemNet maps was assessed. The study discussed in the second paper describes the use of SemNet in a technique for assessing the extent to which students can recall and apply specific verbal and diagrammatic knowledge in the domain of geometrical optics. The goal was to apply this assessment strategy to compare student learning in two different learning environments: one making extensive use of computer-videodisc technology; the other a more traditional instructional environment. The two resulting assessment instruments were used to examine differences in student understanding resulting from the two learning environments. The third and fourth papers discuss alternative approaches to the automatic generation of overviews -- 'executive summaries' of the main ideas in a network, intended to provide insights into the style of net organization, the perspective or focus that influenced net construction, the completeness of a net for a given purpose, and where a particular concept is located in the overall net structure.

MICROCOMPUTER BASED KNOWLEDGE REPRESENTATION IN PRESERVICE ELEMENTARY SCIENCE EDUCATION

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This paper addresses the use of microcomputer based knowledge reconstruction in terms of teaching, learning and curriculum development in preservice elementary science education programs. SemNet software is used to facilitate teachers and student knowledge reconstruction and representation in semantic networks. Preservice teachers enrolled in science courses constitute the population of the study. The research team used SemNet as a teaching strategy in three science classes. Teacher's comments on the use of SemNet maps as an instructional vehicle were assessed. Student generated SemNet maps were evaluated according to numbers of concepts, relations and instances. Finally, preservice teachers' ability to plan curriculum through sequencing of science concepts, instructional strategies and learning outcomes in their SemNet maps was assessed. The conclusions of the paper point to the pedagogical benefits derived from the process of knowledge reconstruction facilitated through interactive software.

A STRATEGY FOR ASSESSING THE EXTENT TO WHICH STUDENTS CAN RECALL AND APPLY SCIENTIFIC KNOWLEDGE

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SemNet was used as an integral part of a strategy to assess student understanding in the domain of geometrical optics. The researchers used SemNet to develop a network of the specific verbal and diagrammatic knowledge that students would supposedly acquire during a three week unit on geometrical optics in an activity-based physics course for prospective elementary school teachers. The knowledge network was then used to guide the development of two assessment instruments: a recall knowledge probe and a problem-solving probe. The recall knowledge probe consisted of a large number of questions, each one corresponding to a specific concept, diagram or instance from the knowledge network. The probe was administered as a paper-and-pencil test to the entire class, and was used to determine if students could recall specific verbal and diagrammatic information presented during the instruction. The problem-solving probe was used to determine the extent to which students could use the diagrammatic and verbal knowledge (from the knowledge network) to account for novel optical phenomena. Demonstration-type tasks were designed, and these were administered to students individually in an interview format. The recall and problem-solving probes have been used to examine differences in student understanding resulting from different instructional approaches for helping student learn geometrical optics.

AUTOMATIC CONCEPTUAL OVERVIEWS OF SEMANTIC NETWORKS

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This paper describes the design, implementation and formative evaluation of methods for generating overviews of computer-based semantic networks. The overviews use the conceptual content of a network to produce summaries of its content. Conceptual overview are automatically generated via a four-stem process. 1) Key concepts are identified through a set of numeric filters, the most useful being a measure of "embeddedness" counting a number of unique two-step paths that can be taken from a concept. 2) Substructures are identified by choosing a once concept and a set of relations that are of interest to generate a subset of the network. These subsets are sometimes small and well-contained (microstructure) and sometimes extensive and spread throughout a network (skeletons). 3) The resulting overview are then displayed in one of three forms: (a) textual outlines or lists of concepts sorted by key features; (b) "scatterings" of concepts in a matrix based on hierarchical, sequential and other relationships; and (c) graphical layouts of subsets of a network. 4) The structure may then be edited by the user to clean up results of this automatic process. This paper describes the above techniques in more detail and presents results of uses of these overviews by teachers and students in classrooms and by researchers in assessment. During presentation at the conference, discussion of overviews and additional ideas for them will be solicited from the audience.

AUTOMATIC OVERVIEWS OF SEMANTIC NETWORKS FROM STATISTICAL AND GRAPH ALGORITHMS

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This paper describes the design, implementation and formative evaluation of methods for generating overviews of computer-based semantic networks. The overviews use statistical analyses of a network to produce summaries of its structure and content. Statistical overviews support a goal for overviews to assess the quality of nets in an objective fashion by applying statistical and graph algorithms to the concepts in a network. The core algorithm in our overviews is a cluster analysis. Three different metric pairs of concepts have been used: 1) an adjacency metric based on direct linkages between concepts; 2) a similarity metric based on the quantity of shared neighbors in the network; and 3) a distance metric which uses standard graph algorithms to compute the shortest distance between each pair of concepts. The results are the displayed in either a hierarchical or a nested clustering display. Because of the size of networks, various methods of reducing the extent of concepts are provided. Advantages and disadvantages of the three metrics and various filters are discussed. The results of uses of these overviews by teachers and students in classrooms and by researchers in assessment are described and evaluated. During presentation at the conference, discussion of overviews and additional ideas for them will be solicited from the audience.

FACTORS WHICH INFLUENCE LEARNING ABILITY DURING A SCIENTIFIC FIELD TRIP IN A NATURAL ENVIRONMENT

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The educational effectiveness of field trips is the theme of this study. The main goal was to obtain insight about the factors which influence students' ability to learn during a field trip, in order to improve the planning and execution of learning field trips. The study was conducted in the context of a one day geological field trip for high school students in Israel. Three domains were tested by observations and questionnaires: (1) The nature of the learning activities during the field trip, (2) Student attitudes to the field trip in which he had participated, and (3) changes in knowledge and attitudes following the field trip. Data was collected from three different points of view - student, teacher, and outside observer at three stages: pre, post, and during the field trip. The research population consisted of 256 students grades 9-11 in high schools all over Israel. Statistical procedures (t test and analysis of covariance) were used in order to determine the effectiveness of age and preparedness on student performance during the field trip. It was found that the age variable had only little significant influence and the preparedness variable was significantly more dominant. The learning activity of students, who were prepared by studying a short unit that focused on cognitive preparation, was significantly better than that of the other students. This finding was strongly supported by the observational reports. In order to determine variables which affect learning during a field trip, a multiple regression analysis was conducted. The regression included 22 different independent variable which were grouped in three categories: background, pre field trip and field trip variables. The dependent variable - "learning efficiency during the field trip" is presented in the multiple regression by students attitudes to their individualized learning. In addition to the field trip variables, only three variables were found to have a significant influence on learning ability of students. These three variables are connected to student characteristics prior to the field trip: a) knowledge level and type, b) acquaintance with the field trip area and c) psychological preparedness. All together they define a "novelty space" for the student getting out on a field trip. If this novelty space is reduced before the field trip then we can expect enhanced learning performance during the field. This suggests that a field trip should be planned as an integral part of the curriculum rather than an isolated activity. The field trip should be early in the concrete part of the total learning activity, and it should be preceded by a relatively short preparatory unit that focuses on limiting the novelty space factors.

COLLEGE SCIENCE COURSES AND C-BASE SCIENCE, ACT SCIENCE, AND GALT SCORES: PREDICTORS OF PROCESS SKILLS AND PHYSICAL SCIENCE MISCONCEPTIONS

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In this predictive study, the C-BASE Science score, ACT Science score, GALT score, and total number of college science courses completed were investigated as predictors of science process skills and physical science misconceptions. Also investigated were the levels of formal operational reasoning, science process skills, and physical science misconceptions of preservice elementary teachers. The literature review uncovered no predictive research studies in which the above variables were used as independent and dependent variables. The sample (N = 29) consisted of four males and 25 females enrolled in an elementary science methods course in a midwestern university with a student enrollment of approximately 20,000. On the average, the subjects were 23.1 years of age (SD = 3.15, with a range of 21-34) and had a college GPA of 3.27 on a scale of 4.0 (SD = .43, with a range of 3.0 - 4.0). The number of college science courses completed ranged for 1 to 8 with a mean of 3.9. Of the sample, 20 (71%) had completed only one physical science course, 21 (75%) had taken only one earth science course, and 20 (71%) had completed one biological science course. Twenty-nine percent of the sample had completed two to four biological science courses. The subjects' average ACT composite score was 23003 (SD = 2.61 with a range of 20-30) with a M = 23.82, SD = 4.12, and range of 16-32 on the Science sub test. Their average C-BASE composite was 321 (SD = 45.46 with a range of 241-414) with a M = 323.52, SD = 62.70, and range of 215-413 on the science sub test. During the first two weeks of classes, the Group Assessment of Logical Thinking (GALT), the Integrated Process Skills Test II (TIPSII), and the Physical Science Test (PST) were administered to the sample. The validation studies on the three instruments indicate that the instruments are valid and reliable. Fifty-nine percent of the sample is functioning at the formal operational level. Correlational reasoning was the most difficult for this sample. Overall, the preservice elementary teachers performed well on the TIPS II. The males performed better than the females. The number of college science courses completed, science sub tests on the ACT and C-BASE, and the GALT score were all significant predictors of science process skills and physical science misconceptions. It was anticipated that the GALT would contribute the most variance in process skills since the criterion-related reliability between the GALT and TIPS II was found to be .71. The C-Base contributed the most variance in understanding physical science concepts. Perhaps this is attributable to the C-Base's emphasis upon reasoning competencies. Finding the number of college science courses, science sub tests on the ACT and C-Base and the GALT score significant predictors of process skills and understanding physical science concepts is reassuring. This finding should be just one indicator that the current admittance standards for teacher education in this state have merit.

THE RELATIONSHIP BETWEEN STUDENTS' APPROACHES TO STUDYING FORMAL REASONING ABILITY, PRIOR KNOWLEDGE, AND GENDER AND THEIR ACHIEVEMENT IN CHEMISTRY

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The two main purposes of this study were 1) to investigate the relationships between students' approaches to studying, prior knowledge, logical thinking ability, attitude toward chemistry, and performance chemistry; and 2) to explore the sex differences on the same variables. Subjects for this study were 220 students enrolled in the second semester of a freshmen chemistry course for non-science majors at a private university in New York State. Complete data were available for 199 students (114 females and 85 males) since 21 of the original group dropped out from the course by the end of the semester. Students were asked to respond to a Demographic Questionnaire, seven sub-scales of the Approaches to Studying Inventory, and The Attitude Toward Chemistry Questionnaire during a lecture in the first week of the 1990 Winter Semester. These same students were administered the Test of Logical Thinking (TOLT) during the first and second weeks of the semester in their respective laboratory sessions. The students' grades on an hourly exam early in the second semester covering the pre-requisite concepts for the course were used as measures of students' prior knowledge. Finally, the second semester cumulative final examination scores were obtained at the end of the Spring semester during May 1990. Students in this study were found to have slightly higher scores on reproducing orientation than on meaning orientation, a pattern which confirms Entwistle and Ramsden's (1983) findings with a similar group of non-science majors. There were significant correlations between final examination and prior knowledge, meaning orientation, and Test of Logical Thinking (TOLT). In addition, there were significant correlations between, achievement motivation and meaning orientation, achievement motivation and reproducing orientation, attitude and meaning orientation, and attitude and achievement motivation. When correlations were computed for males and females separately, meaning orientation was significantly related with final exam for males but not for females, while TOLT was significantly correlated with the final examination for both genders. The results of a stepwise multiple regression showed that the prior knowledge, TOLT, and meaning orientation were significant predictors accounting for 32% of the variance on the final examination score. When the total sample is considered, the results of this study confirm the previous findings in the United States and Egypt (e.g. Lawson, 1983; Zeitoun, 1989) that prior knowledge is the best predictor of achievement, while formal reasoning ability is the next best predictor. Also, the results of this study confirm the findings in Great Britain and Hungary that a significant relationship exists between meaning orientation and achievement in science.

GENDER DIFFERENCES: WHAT SHOULD WE DO IN THE CURRICULUM TO MAKE A DIFFERENCE?

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Student attitudes toward science decline dramatically in the middle school years (NAEP, 1988). This trend is particularly evident in female and minority students. This unfavorable shift in attitudes and interest in science is one of many indicators of a tremendous need to improve middle school science. One critical aspect of this improvement effort is the middle school curriculum. Before we can develop an ideal curriculum, however, we must discover how to meet the unique needs of middle school students. In this study, we interviewed 72 students and surveyed approximately 1000 students in grades 6-8 to learn more about their interest in and attitudes toward science and technology. One of the subsections of data we examined was the differences in male and female students. Our preliminary analysis shows some surprising findings; girls like science and in fact indicate a higher level of interest in science and technology topics than boys do. These data have marked implication for curriculum development and teacher education. Perhaps it is not what we are teaching in science that is affecting attitudes, but how we are teaching science.

EFFECT OF USING CULTURALLY-RELEVANT SCIENCE CURRICULUM MATERIALS ON NATIVE AMERICAN ELEMENTARY STUDENTS

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The 1980's national reports and studies for A Nation at Risk (National Commission, 1983) to The Science Report Card (Mullins & Jenkins, 1988) and Who is in the Pipeline? (Vetter, 1990) have pointed out America's increasing numbers of "at risk" students and their shocking performance in school, including science achievement and pursuit. Reports specific to Indian education such as the Bureau of Indian Affairs' Report on Indian Education (1988) and the charge to the U.S. Department of Education's Indian Nations at Risk Task Force (1990) have addressed these problems for America's first people. One of the many strategies suggested to address these complex problems has been the inclusion of culturally-relevant curriculum materials in all subjects in schools serving Native American students. Science and mathematics have been especially noted as important curriculum areas requiring special attention. This study, carried out in BIA reservation schools serving 11 tribes in five states, tested the hypothesis that attitudes toward science of young students are positively affected by the use of curriculum materials that make frequent reference to the students' cultural heritage and prior experience. Although the study was limited to Native American students, it has more general applicability to the oft repeated, but seldom directly tested hypothesis that students learn better when their curriculum materials are perceived by the students as relevant to their own lives. It was concluded that Indian-related materials do have a positive effect on attitude of American Indian elementary school students in science.

FACTORS ENCOURAGING PARTICIPATION OF WOMEN IN SCIENCE AND TECHNOLOGY

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The underrepresentation of women in science is a sequence of cascading losses where women are proportionally fewer at each level and stage of education, fewer at tertiary level than secondary, fewer in postgraduate than undergraduate, fewer in doctoral enrollments than masters. This paper reports part of the project, Women in Science and Technology in Australia (WISTA) which was established in order to examine positive factors which aid women's participation in science and technology education and employment and to examine the barriers they encounter. The study reported was the educational experiences of 150 practicing scientists in six areas which Australian Bureau of Statistics figures showed to be non-traditional for women. A cluster analysis of the interview data showed seven distance profiles of positive and negative factors. Of the seven, one cluster was comprised chiefly of women and showed the influence of a constellation of factors which have been recognized as supportive for recruitment and retention of women in science and technology. It enabled an examination of the relationship of positive and negative factors.

ATTITUDE CHANGE AND GENDER - EQUITY IN SCIENCE: COMMUNICATOR QUALITIES THAT ENHANCE PERSUASION

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Persuasion is not something done to a relatively passive and defenseless receiver, but is the product of an interaction between a source and a receiver. Viewed from this perspective, persuasion is an appropriate means by which policy regarding gender-equity in science can be translated into practice. Based on tests of Petty and Cacioppo's Elaboration Likelihood Model (ELM) of persuasion, it is suspected that strong arguments alone are not sufficient to modify the subtle biases and differential expectations for girls and boys of all who listen to a persuasive message. Thus, what listeners believe about a source will have a decided effect on the persuasiveness of the message. The observation that some people are more persuasive than others led to the investigation of characteristics of successful communicators. Credibility, attractiveness, and power are the source qualities found to function in persuasion. Internalization is the process by which highly credible sources are thought to change attitude; attitudes changed through internalization are likely to endure. Credibility stems from a source's perceived expertise and trustworthiness. Attractive sources inculcate or modify attitudes through identification. Various factors seen to account for why a source is considered attractive including good looks, familiarity, and similarity in appearance or attitude. Powerful sources alter attitudes by means of compliance. Power may be derived from one's ability to dispense rewards or punishment, or from the legitimate authority extended by social institutions. A number of persuasive skills can be taught and thus used as a source to increase an audience's perception of one's credibility, attractiveness, or power regarding the issue of gender-equity in science. Telling of one's past accomplishments, raising anticipated objections during a speech, smiling when appropriate, and offering rewards for agreement are just a few of the persuasive skills that can be invoked by a message source. When using these skills the ethical responsibility of the source can not be neglected. The message source is not the only factor that affects attitude formation and change. But awareness of the message source's role in the persuasion process is vital to an understanding of how persuasion can be used to promote gender-equity in science.

THE EFFECTS OF THE SEQUENCE OF LABORATORY-CLASSROOM INSTRUCTION AND THE LEVEL OF REASONING ON STUDENT ACHIEVEMENT

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The purposes of this study were: (1) to test the hypotheses that students introduced to new science information (diffusion in a cell) through laboratory exercises learn and retain that information better than students taught through textbook readings and teacher lectures followed by verification labs; and (2) to determine if the student's "level of reasoning" as measured by the Sund test had an impact on learning and retention. The interaction effects between the sequencing of learning activities and students' levels of reasoning were also examined. The study group was composed of six ninth grade biology classes located in a suburban high school near Cincinnati, Ohio. The control classes read and discussed diffusion in cells before performing laboratory exercises, while the treatment classes performed the laboratory exercises before reading and discussing the content in class. A pretest, immediate posttest, and delayed tests were used to compare the achievement and retention of the two groups. A 2 X 3 multivariate analysis of covariance was employed to analyze the effects of two levels of sequencing and three levels of cognitive reasoning on immediate and delayed posttest scores. The performance of students who experienced laboratory exercises before classroom discussions and textbook readings was compared to performance of students who experienced the same laboratory exercises before classroom discussions and textbook readings. In addition, the performance of concrete, transitional, and formal level reasoners was compared. In all comparisons, pretest scores and scores on a standardized test call the School Ability Index (SAI) were used as covariates. The results indicated that the sequence of instructional activities did not influence immediate or delayed posttest scores, but that the level of reasoning did have an impact. Students who used higher levels of reasoning performed significantly better than those using lower levels of reasoning. The results of the study are interpreted in terms of constructivism, and the implications of the findings for classroom teachers are discussed. In addition, recommendations for further research will be proposed.

LEARNING IN UNDERGRADUATE CHEMISTRY LABORATORY AS AN APPRENTICESHIP. INCREASING EXPERT LABORATORY SKILLS IN FIRST YEAR CHEMISTRY STUDENTS

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The University of Michigan Chemistry Department has instituted a comprehensive change in its undergraduate curriculum. The cornerstone of the new sequence is a year-long course for first-year students titled Structure and Reactivity. This course uses the content of the traditional sophomore organic chemistry course as its context. In 1990, 700 of the approximately 2500 first-year chemistry students started with Structure and Reactivity as their first course. The explicit course design and delivery of Structure and Reactivity are focussed on using the disciplinary content as a vehicle for providing students with the opportunity to develop and practice useful models for inquiry. Specifically, we have found that the organic chemist's model for structure and reactivity relationships provides an easy way to engage students in higher level inquiry. In the laboratory portion of the course, this approach has dramatically altered our concept of the hands-on experience. As in the lecture portion of the course, any particular content item is viewed as a means to some more meaningful end that is connected to the observable and comprehensive world. The traditional models for classroom laboratory instruction is derived from our experiences in directing research for novice students. The concept of learning chemistry by doing chemistry as an apprentice is the way chemist train in the research laboratory. We have attempted to extract the essence of this experience and to use the context of the laboratory course in order to create an environment that allows an introductory student to participate in a more authentic scientific activity. Proficiency is developed via the iterative practicing of an authentic activity under the mentorship of an expert. We have identified a number of characteristics for creating the chemistry apprenticeship. We have collected data on how the expert skills of a group of the Structure and Reactivity students compare with those of a group of students form the traditional sophomore organic laboratory course, using faculty and graduate student responses as the reference point. We have used the responses to an interview about the design of an approach to solving a laboratory task. We have looked at how the two groups of student responses compare with the expert responses by creating the concept maps of their respective approaches based on the transcripts of the interviews. By comparing the concept maps, the Structure and Reactivity students had a more expert view of the problem than the traditional students. The expert view of our particular laboratory problem had three clear phases: analysis, separation and identification scheme, and they were consistently able to suggest more sophisticated resolutions with a higher personal confidence. The benefits of hands on experience with instrumentation were also evident. The abilities demonstrated by the Structure and Reactivity students reflect a more expert conception and philosophy about science practice than those of the traditionally-trained students.

THE EFFECTS OF FREE EXPLORATION FROM HANDS-ON SCIENCE CENTER EXHIBITS

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The purpose of this study was to explore the link between conceptual understanding, free exploration of hands-on science center exhibits, and Piagetian cognitive developmental levels. In this primarily qualitative study, which is based upon interview and observational data, patterns in children's behavior relating to specific hands-on science center exhibits are described. The cross-age sample of 50 children is representative, socio-economically, of the typical young science museum visitor. The researcher's contact with the children extended over a three month period in which each child was interviewed three times for at least half and hour at each interview. The data gathering included selecting four exhibits, two which attempted to convey a concrete concept and two which presented a formal concept. A concept statement was written for each of the exhibits. One exhibit in each category was selected because the interaction was limited to pushing a button and observing an action. Each subject was interviewed and tested using a set of eight Piagetian tasks. The subjects were then divided into three categories: pre-concrete, concrete, and post-concrete. An attempt was made to have an equal number of males and females in each group. Initial findings include the following: 1) subjects that brought no previous knowledge to a formal concept exhibit, left with specific misconceptions; 2) pre-concrete subjects attributed the motion of an air foil in a Bernoulli's principle exhibit to pushing the button; 3) concrete and post-concrete subjects maintained that the air blowing through the air tunnel actually went under the air foil and lifted it; 4) there were no differences in concept understanding attributed to gender in any of the three groups, although more girls than boys seemed to lack confidence in their answers; 5) the label on the exhibit did not assist the subjects in understanding a formal concept exhibit. Each year millions of dollars are spent by schools on field trips to science museums with the belief that the visit is educational, yet little research has been done to assess the educational impact that hands-on science museum exhibits have on the visitor. Studies like this are significant because they suggest directions for improving exhibits, school field trips, and a method for determining the effectiveness of informal learning experiences.

ISSUES AND QUESTIONS RELATED TO SCIENCE CURRICULUM REFORM: A PANEL DISCUSSION ON SETTING A RESEARCH AGENDA

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On April 8, 1990, a group of thirty educational researchers, sociologists, scientists, science teachers, professional society representatives, curriculum specialists, school policy analysts, and fund agency staff convened at the Atlanta Hilton Towers for a meeting to discuss issues critical to science curriculum reform. The meeting was sponsored by the National Association for Research in Science Teaching and funded by the National Science Foundation. The meeting, stimulated by national calls for science curriculum reform to prepare a scientifically literate citizenry, had as its objective: To generate a research specifications document which could be used by curriculum developers, educational and policy researchers, publishers of curriculum materials, funding agency staff and school personnel to both inform the process and gauge the impact of current science curriculum reform efforts. Meeting participants were chosen from a range of educational and research communities to ensure a broad base of discussion. Many of the participants had not met each other previously and when initially invited, several expressed reservations about what they might be able to contribute to a discussion of science curricula. But because of their unique backgrounds, a diverse set of issues was shared. It was clear from discussions and precis that the process of curriculum reform, like the educational process itself, is embedded within levels of the classroom, school community, government and society cultures and that a research agenda must necessarily include not only questions about the influence of policy, values, beliefs and commitments at each level, but also questions about the interactions among these levels. This panel will focus on the report of that Atlanta meeting, i.e., the nature of curriculum, the forces and factors which influence curriculum and reform, and recommendations for conducting research related to curriculum reform.

WHAT SHOULD BE TAUGHT AND WHY: THE BELIEFS OF PRESERVICE SCIENCE TEACHERS

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The task of teaching preservice science education students how to select what to teach is important. How to approach this task can be informed by a description of what the preservice students initially believe they should teach. The purpose of this study was to: determine what types of science knowledge preservice students believe should be taught, and the types of reasons they provide to justify their choices. The seventeen subjects for the study were enrolled in their first science methods course. During the first class session the students were asked to plan a lesson in their scientific field for eighth grade students. They were required to specify the specific knowledge the eighth graders were to learn and then describe the instruction they would provide. In each case, the students were asked to provide their reasons for their decisions. The students' statements regarding what to teach were categorized to identify the scientific structures and functions that their statements represented. The students' reasons were categorized in terms of widely accepted views of why science should be taught. Additional qualitative analyses were used to interpret the frequencies of the students' responses. The results showed that students began their science methods course with the conception that teaching scientific content was the primary goal. Seventy-six percent of the student responses were statements about teaching "the types of levers", "the definition of enzymes" or " the basic characteristics of plants". Interest in teaching the nature or history of science and teaching the functions of science combined was limited to approximately 18% of their responses. The students' reasons for teaching specific science knowledge were somewhat more varied than was their selection of what to teach. Approximately 44% of the students' reasons were academic, that is, because the knowledge promoted understanding the discipline. Twenty-four percent of the students' reasons were based on their view of their students' abilities and motivations. Seventeen percent of the students' justifications were in terms of what the knowledge would contribute understanding the history and philosophy of science. Preservice students in this study were clearly interested in selecting the structures of science, primarily content, for students to learn. Their view of what should be taught is a misconception that needs to be addressed directly. A starting point for changing this "content only" misconception may be found in the students' modest number of justifications that were related to the history and philosophy of science. If students can be taught to consider the multiple functions and values of science, then they may be able to adopt a broader, more balanced perspective regarding what should be taught. The results also suggest that preservice science education students do consider the nature of the students that they will teach at least in a modest way. What seems to be necessary is that the preservice students learn specific ways of assessing their students' abilities and motivations prior to planning, then explicitly employing the results of their assessments in planning what to teach.

WHAT'S A TEACHER TO KNOW?

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This paper reports on on-going longitudinal case study research to document the development of secondary science teachers' knowledge about teaching. Much current research in teacher education has focused on describing and explicating the kinds of knowledge that excellent teachers have and use in their practice. The delineation of this knowledge is difficult because much of what good teachers do is based on tacit knowledge. The longitudinal research reported on here aids in the delineation of expert teacher knowledge by describing what preservice teachers know about teaching, what they don't know when they begin teaching, and what they begin to know during their first teaching. The paper presents first the underlying assumptions and theoretical frameworks that guide the paper. There is a discussion of the definition of good teaching used in the paper and discussion of several of the ways in which teacher knowledge has been studied. The paper then describes the methods used in the case study and discusses the findings already analyzed. Further data will be gathered during the Fall of 1990 and these data will be analyzed for the spring presentation.

PRESERVICE BIOLOGY TEACHERS' SUBJECT MATTER STRUCTURES AND THEIR RELATIONSHIP TO THE ACT OF TEACHING

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Ten preservice biology teachers were followed throughout the final year of their preservice education to assess the content and stability of their knowledge structures of biology. A questionnaire asking the subjects to list the topics which make up biology and to diagram these topics in relation to one another was completed three times during the Fall Term. The questionnaire was completed again in the Spring Term during student teaching and was followed by a 30-minute interview. Qualitative analysis of the data attempted to derive any evident patterns among, and within, the preservice teachers' stated subject matter structures. Despite having essentially completed the biology content portion of their program, few preservice teachers reported possessing a coherent structure of subject matter, or have thought about the topics which make up biology, prior to completing the questionnaire. In addition, these knowledge structures were found to be extremely fragile and strongly influenced by the opportunity to think about how subject matter would be conveyed to students. The act of teaching and courses specifically related to science teaching provided an underlying integrated theme for biology topics which students originally perceived as isolated as a result of their college science coursework. Although the preservice teachers eventually recognized popular advocated goals of science education (i.e., science-technology-society interactions and the nature of science), few preservice teachers felt they could adequately address such goals within the context of student teaching where priority was given to day-to-day planning and classroom management. These results suggest that courses in science education may be the natural and most effective location for initial reflection on the integrating themes of science, by that the translation of such understanding may not be realistic for the novice teacher. Since many of the new reforms in science education depend on the incorporation of integrating themes, inservice programs may be critical to foster teachers' reflections on subject matter structure and its translation to science instruction.

METHODOLOGICAL PERSPECTIVES ON THE ROLE OF TECHNOLOGY IN RESEARCH ON STUDENT USE OF SCIENCE SOFTWARE

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As microcomputers in science classrooms have opened up new possibilities for instruction, their use by students has emerged as a potentially important new source of raw data for educational research. Computers also often play a major role in the gathering and analysis of such data, but several methodological problems have arisen among researchers in this field. The capacity of computer and video technology automatically and inobtrusively compile large amount of highly detailed data has thus far largely outstripped the ability of commonly-used analytic methods to make sense of this wealth of potentially useful information. This discussion focuses on both the potential benefits and the real limitations of automation in the analysis of these data, especially of videotapes and computer compiled "traces" or "log files" of student behavior. We offer contrasting perspectives from research on student use of four different major types of science-related educational software: a genetics simulation, a graphical data analysis utility, microcomputer-based laboratory materials, and a videodisc-based hypermedia learning environment for chemistry. A variety of approaches to the computer-assisted analysis of student performance data are also included. These range from qualitative protocol analysis to regression-based multivariate modeling to sequence comparison and cluster analysis techniques. Contrasts between qualitative and quantitative approaches, and their possible integration, are discussed.

AN ASSESSMENT OF FACTORS RELATED TO ATTRITION OF SCIENCE AND MATHEMATICS TEACHERS

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A survey was conducted with mathematics and science education majors graduating from a midwest state university during the years 1975 through 1989. The purpose of the survey was to determine the factors that may impact on teacher decision making to remain in the profession, drop out, or never enter the profession. In addition, the survey gathered information to assist teacher educators with planning program improvements. Reasons given for leaving the teaching profession were mainly low salaries, too many extracurricular activities that left little time for adequate class preparation and family, discipline problems, lack of support from the administration, and poor quality of teachers in the system. For those that never entered the teaching profession, twenty-eight percent of them did not because they were unable to find a job. Thirty-five percent found higher paying jobs outside the profession. Eleven percent wanted to raise a family, and twenty-eight percent changed their mind about teaching because of their student teaching experience. The main factors cited that could enhance teachers to stay in the profession were higher salaries, a significant reduction of extracurricular activities, more teacher input in school board decisions regarding schedule and curriculum, and more teacher control in discipline situation. Information was also gathered regarding the student teaching experience, the cooperating teacher and educational courses offered at the University (courses that should be emphasized and additional courses that should be offered). It was strongly recommended that the university teacher education program should endeavor to offer a teaching field label for the four years of the curriculum. As part of the teaching lab, students should visit secondary classes (three times per week, an hour each time) schools as observers and as teacher assistants. It was suggested that this will expose the students from early on to the classroom environment, to the problems encountered in daily teaching, and to classroom management strategies. During the second two years (after knowledge in subject matter has been acquired), students should be involved in preparing lesson plans for every subject they will be certified to teach, according to the latest secondary school textbook used in the schools being offered. Students should teach from these lesson plans on a regular basis to their peers under the supervision of their university professors. The last semester of their four year study students should be involved in a variety of classroom teaching experiences and cooperating teachers at secondary schools. As such, the program would provide a variety of perspectives and be dependent if at all on finding an exemplary cooperating teacher willing to take each student teacher. In addition to student visiting schools, the teaching lab should offer videos of practicing teachers and master teachers. This would give the students examples of real teaching situations on a wider scale.

RESEARCH INTERESTS: COMPARISON OF PRESERVICE AND INSERVICE ELEMENTARY TEACHERS

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The primary purpose of this descriptive survey study was to compare the research priorities of preservice and inservice elementary teachers. Secondary purposes included (a) determining the research priorities of preservice elementary teachers, (b) investigating the differences in research priorities according to gender, (c) investigating the differences in research priorities of preservice elementary teachers according to grade level choice (i.e., K-4 or 5-8), and (d) investigating the differences in priorities of preservice elementary teachers according to the number of college science courses completed (i.e., 1-3 or 4-12). The review of literature focused on the role of research in science teaching and science education interest of inservice elementary teachers. The sample (N = 87) consisted of four sections of preservice elementary teachers enrolled in the course "Teaching Elementary Science Methods" at a midwestern university with an enrollment of approximately 20,000. Even though all students currently enrolled in the elementary science methods course were included, the sample should be considered representative of elementary majors at this university. Of the sample, 80 teachers were female and seven were male. The National Science Teachers Association Survey of Elementary Teachers on Research Interest was administered to the sample the first day of the semester. This questionnaire consists of 28 Likert-type items focusing on science related research topics and eight demographic questions. The demographic questions were modified to fit the background of preservice elementary teachers. Student records were checked to verify the number of college science courses completed. The data are reported in frequencies and percents. Seventy-nine percent desired to teach K-3 and 21% indicated grades above third. Sixty-four percent of the sample had completed three or less college science courses. The McNemar was significant (a) for the sample in hands-on experiences and science content of the curriculum, (b) for the sample in science fairs and sex differences, (c) for females in hands-on experiences and science content of the curriculum, and (d) for females in role models and science careers and sex differences. Preservice and inservice elementary teachers selected cognitive development and learning styles, hands-on experiences, and problem-solving as one of their top five research priorities. In addition to the above three topics, the preservice teachers rated slow learners, interdisciplinary teaching of science with mathematics and language arts, science learning centers, and disadvantaged children as highest research preferences. The inservice teachers identified sequencing of science content, barriers to teaching science, effective printed materials, and science classroom experiences and pupil attitudes as among the top research priorities. Consensus was found between the preservice and inservice teachers in their rating of role models and science careers, language difficulties, science fairs, misconceptions, and sex differences as lowest research priorities.

PREPARATION OF SCIENCE AND MATHEMATICS TEACHERS FOR THE TWENTY - FIRST CENTURY

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A National Science Foundation (NSF) project has begun in undergraduate teacher preparation to introduce technology and a constructivist approach to teaching in physics, chemistry, mathematics, statistics, science education and mathematics education courses at the university. The project teams scientist and science educators, and mathematicians and mathematics educators who are working collaboratively to change 13 undergraduate courses in the science and mathematics education curricula. There are 150 science education and 200 mathematics education undergraduates at the university. The project proposed to address the misconception among undergraduates that telling is teaching and listening is learning. The assumption is that if future teachers actively learn science and mathematics using technology, they will be confident and knowledgeable about using hands-on methods and technological tools in their precollege teaching. A comparison was made between the project faculty with a random sample of their colleagues, before the project began and after one year of the five-year project. The base-line data indicated that the two groups of faculty were not different from one another in their use of instructional methods, with the exception that the NSF project faculty used inquiry and guided practice more than the non-project faculty. Neither group used technology in their instruction of undergraduates with any frequency, nor were their attitudes different toward computers before the project began. Survey results after one year indicated that the NSF project faculty taught differently from their colleagues; they lectured less and used cooperative learning, discussion, and inquiry more than the non-project faculty. The project faculty had more positive attitudes about using computers and calculators than their colleagues. Also, the project faculty had more positive attitudes about computers than they had in the previous year. Some differences in the project faculty's use of technology in instruction have begun to emerge. We recognize that lasting innovations take place over five to ten years and the faculty's perceptions of teaching and learning will be different each year that they are actively involved in the project.

COULD SCIENTIFIC REASONING BE THE BASIS OF ALL COGNITION?

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This paper explores the implications of some new research results which suggest that the claims for scientific thinking to be the foundation of a broad range of cognition may not have been as over-optimistic as we have recently come to believe. A set of 30 activities set in science contexts which emphasized cognitive conflict and metacognition were developed, with the express view of encouraging the development of formal operational schemata. These activities were used in grade 6 and grade 7 classes in 9 schools of varied characteristics, with one activity replacing a regular science class every two weeks for two years. Measures of cognitive development showed significant gains for the experimental group as compared with controls at the end of the intervention program. The sample was followed-up further for two years: those who had experienced the intervention were found to perform significantly better in a national public examination taken two years after the end of the program - not only in science (effect size for boys was 0.7), but also in mathematics and in English language (effect size in English was 0.4 for girls). There is evidence for a casual link between the cognitive gains made during the intervention program and subsequent improved learning. Notwithstanding some important gender differences in the effects, this provides evidence of long-term-far-transfer from the training context to other domains. The paper will look at the implications of such transfer, results for models of cognition, and for the future of science curriculum development. If the results are substantiated by replication, models of cognition which incorporate a central processing structure general across domains may regain some of the ground lost in recent years to domain-specific models. Further, some hope is held out once again for science as being an especially favorable epistemological environment for the nurturing of general thinking skills. The possibility of directly influencing the effectiveness of our students' central cognitive processors will be seen as a realistic goal in ordinary schools with ordinary teachers. The approach to be described was deeply constructivist: the activities developed are such that students must construct for themselves not just the knowledge and concepts, but also the very thinking processes by which those concepts are acquired. This might be described as "meta-constructivism". Implication for the kind of science that might deliver general thinking skills will be discussed, and so for the direction in which science curriculum development might profitably move during the next decade.

UNDERSTANDING A BASIC BIOLOGICAL PROCESS: EXPERT AND NOVICE MODELS OF MEIOSIS

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The subcellular process of meiosis is one of the most important and difficult topics in the basic biology curriculum. In this paper, I report on the meiosis models displayed by individuals at varying levels of expertise (from introductory college students to practicing geneticists) while solving a problem that required direct reasoning about the process. From the detailed microanalysis of individuals' meiosis models, I (1) categorize a variety of meiosis misconceptions, some of which occurred at all levels of expertise, (2) suggest possible sources of specific misconceptions, many of which are based in instruction, and (3) distinguish between skeletal pieces of knowledge that are easily incorporated into an initial meiosis model and other pieces of knowledge that prove more problematic to the construction of a detailed and accurate model of meiosis. The third result serves as the basis of a partial model of how individuals construct meaningful and accurate understanding of meiosis. Finally, I derive instructional implications from the potential sources of specific misconceptions and from the more general model of constructing understanding.

A STUDY OF THE EFFECTS OF PREDICTION ACTIVITIES ON INSTRUCTIONAL OUTCOMES IN HIGH SCHOOL GENETICS

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The decline in attitude toward science and motivation during the middle and secondary grades, as well as the call for emphasis on both process skills and thinking skills in the science classroom, gave impetus to this research project. The purpose of this study is to examine the effects of prediction activities on instructional outcomes in a high school genetics unit. Students will be asked to make predictions about the patterns and mechanisms of inheritance, as well as explain, justify, and discuss their predictions. Criteria of effectiveness will include the following enhanced levels of classroom discussion and interaction: improved subject-related attitude, higher achievement motivation, and greater mastery of genetics concepts. One of the primary goals of science education is to assist students in becoming more competent problem solvers. Genetics was chosen as the domain of research because of the nature of the problems presented. Manipulation of multiple variables and formal level thinking are required to comprehend many of the mechanisms of inheritance. These multiple variables are amenable to the making of predictions. The prediction activities include nineteen prediction sheets developed by the researcher, each focusing on a different genetics topic. Students in the treatment classes will participate in the prediction activities. The study employs both quantitative and qualitative analyses of the treatment and its effects on instructional outcomes. Quantitative measures include pretest/posttest genetics achievement scores as well as pretest/posttest scales. Qualitative descriptions comparing the treatment and control groups on evidences of student interest, discussions, and argumentation about the genetics topics will be completed by the teacher/observers in the classrooms. This study should establish a sound research base from which other studies concerning prediction can be done. Information gained should generate recommendations for more effective instructional strategies for teaching the concepts of genetics and problem solving and can have broad implications for the teaching of science concepts that require manipulation of variables for the solution of problems. During September and October of 1990 four experienced high school biology teacher/researchers will each have a treatment class and a control class participating in the larger study.

ANALYSIS OF THE PRESENTATION OF THE MOLE CONCEPT IN CHEMISTRY TEXTBOOKS

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The authors' purpose in this study was to examine the definitions and conceptual models used to introduce and explain the mole concept in high school and introductory college chemistry textbooks. The examination consisted of careful reading by both authors of those sections of the text in which the mole concept was first introduced and defined. The glossary was also examined. Finally, the authors examined whether or not the concept of isotopes was presented prior to introduction of the mole concept and whether or not the text presented Avogadro's constant as an empirically determined value with any uncertainty. Results indicate that wide variations exists in the way the mole concept is defined in texts. High school level texts usually define the mole as Avogadro's Number; in contrast college level text define the mole more frequently according to its definition in the International System of Units. Texts using the SI definition of the mole usually introduce the concept of isotopes prior to introducing the mole. Conceptual models of the mole as presented in texts most often emphasize its numerical value (Avogadros' Number) in making chemical calculations. Implications for introducing the mole concept in texts and oral presentations are discussed.

DO MIDDLE SCHOOL LIFE SCIENCE TEXTBOOKS PROVIDE A BALANCE OF COVERAGE OF SCIENTIFIC LITERACY THEMES?

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Science textbooks play an important role for middle school science teachers in the education of our youth. These teaching aids often form the topic outline of the curriculum and contain a significant amount of the information addressed in the classroom. Many science teachers, new teachers in particular, use the assigned textbook as their content outline and story-line for their courses. Some researchers believe that in a typical classroom the textbook serves as the ultimate source of knowledge, provides the majority of instructional support beyond the teacher, and in many cases, actually becomes the curriculum. If science textbooks are so important, they must present the nature of science within a relevant context to students and go beyond merely presenting science as a body of knowledge. Four themes of scientific literacy have been synthesized to analyze science textbooks for this purpose: 1) science as a body of knowledge; 2) science as a way of investigating; 3) science as a way of thinking; and 4) the interaction among science, technology, and society (STS). These ideas were synthesized from the NSTA's 1982 position on scientific literacy and the work of many other science educators. The purpose of this investigation was to analyze five life science textbooks for their presentation of the four themes of scientific literacy. Science as a body of knowledge is the predominant theme in the five textbooks, ranging from a mean of 54% to 76%. The mean range of the material in these textbooks devoted to science as a way of investigating is 22% to 41%. The mean range of the material devoted to science as a way of thinking is 0% to 2%. The mean range devoted to STS is 3% to 11%. The life science textbooks examined in this study, which have been used in many middle school science classrooms across the nation, seem to stress two aspects of scientific literacy -- science as a body of knowledge and science as a way of investigating. These textbooks devote practically no text to science as a way of thinking. There is little regard for how ideas were discovered, how science proceeds (inductively or deductively), or how scientist experiment to form new knowledge. Very little text is devoted to the interaction of science, technology, and society, in spite of the fact that many science and technological advancements occurred in the life sciences prior to the writing of these textbooks. There was at least one chapter in each textbook that addressed the nature of science and its relationship with life science.

HOW WELL DO THE MOST USED SCIENCE TEXTBOOKS IN SECONDARY SCHOOLS COVER THE INTERRELATIONSHIP OF SCIENCE, TECHNOLOGY, AND SOCIETY?

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Following the NSF Status Studies (Weiss, 1978; Stake and Easly, 1978) and the Project Synthesis report (Harms and Yager, 1981), many science educators were astonished to find how important the textbook was in determining what students experienced as they studied science. Some researchers reported that the status of school science could be summarized with one word: textbooks. Ninety percent of all science teachers used their textbooks in excess of ninety percent of the time. Further, students expected the textbook to be used as the source of nearly all information and as the determinant for each course he/she experienced. The purpose of this study was to examine eleven most commonly used science textbooks concerning their treatment of interrelationship of science, technology, and society (STS) which was an emphasis NSTA in its Position Statement of the 1980s called upon as a major goal in science education. The importance of this study comes from the extent of the instruction in U.S. schools which the eleven books command. A review of these textbooks provides assurance that the findings can be generalized as being the science that most U.S. students experience. The eleven textbooks analyzed in this study were selected from Weiss (1978) listing of the most frequently used ones in the secondary schools in the United States. The criteria for examining of the interrelationship of science, technology, and society (STS) were adapted for the desired learning objectives and sample topics arising from Project Synthesis and Piel's report (1981). All the pages of the textbooks were examined. The relevant passages in the narrative were identified and further classified into various STS topics. The space of the passage devoted to each specific topic was then measured and recorded in terms of percentage of a full page. The sum of total page space devoted to specific STS topic and its proportion of the total narrative were then determined for each textbook. Rater reliability in terms of percentage of the agreement of the first and the second set of the codings was 98%. The results reveal that major science textbooks are deficient in their treatment of STS topics. Further, the data show that, as the grade level increases, the percentage of the total narrative page space devoted to STS passages decreases ranging form 11.5% to 0.49%. It is also observed that the STS information in the texts is usually presented as fact/statements; rarely are the debatable social issues discussed. Thus, the students are not offered opportunities to familiarize themselves with the science-related problems existing in society. Nor are they introduced to the possible alternatives for solving these problems. They are not prepared or equipped to become good decision makers as functioning citizens of the society.

THE SCIENTIST AS CRACKER-BARREL PHILOSOPHER: IMPLICATIONS FOR THE CONCEPT OF SCIENTIFIC LITERACY

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This study aims to identify an internally consistent and readily teachable philosophical approach to the nature and practice of science, providing a fresh perspective on the current debate over the definition of "scientific literacy". The inspiration and primary source for this effort is anecdotal and autobiographical material prepared for the semi-popular media by an eminent contemporary scientist, the late Richard Feynman. Examples of "real people" working on practical problems in science and technology can be more conducive to sustained classroom discussion than more distant references to prominent figures in the history of science. Richard Feynman's anecdotal reflections provide a model of a scientist who combines a theoretical bent with a personal background anchored in practical problems, and the traditional credentials of authority (the Nobel Prize, etc.) with a transparent humanity. I propose that the infusion of selected Feynman episodes, on video and imprint, can contribute an added level of inspiration and understanding to a science or teacher education curriculum which seeks to ingrate historical and philosophical insights into the nature of scientific thinking. Individual ideas distilled from Feynman's non-technical books, lectures, and television appearances are first compared and contrasted with some recent discussion of scientific literacy and the role of the history and philosophy of science and technology in science education. Stated and implied elements of Feynman's philosophy are then synthesized and examined for their relevance to middle and secondary school science curriculum and classroom practice. These include, among other topics: an irreverent, yet reverent approach to science; the interdependence of scientific facts and science processes; the crucial role of mathematics and mathematical thinking in science; the distinction between science and technology; the nature of interdisciplinary thought and practice; the great cost of the separation of the "two cultures" of science and art; the powerful influence of family atmosphere and childhood experiences on intellectual development. A preliminary evaluation of Feynman's published materials as a resource for science teacher education are explored, based on limited experience of their use with preservice teachers.

ALBERT EINSTEIN: A CASE STUDY OF HIS UNIQUE THINKING STYLE

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This study is an attempt to develop an understanding of aspects of Albert Einstein's unique thinking style that liberated him from the bonds of scientific orthodoxy. Einstein's thought process was characterized by such dimensions as holistic thinking, visual formulation, bimodality, intuition and interpretation. His thinking style was not only undervalued but actually punished in educational settings. Science educators concerned with the need for fitting the school to the student, rather than fitting the student to existing school structures, can benefit from insights gained through an examination of Einstein's thinking style. A study of the exceptional features of his thought process may demystify the fabled picture of an objective view of knowledge that bears no relationship to the thought process of the knower.

HOME SCHOOLING, SCIENCE ACHIEVEMENT, AND PARENT'S BELIEFS ABOUT GOD AND THE ORIGIN OF SPECIES AND LIFE

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The purpose of this study was to explore whether there is a relationship between the science achievement (and general academic achievement) of students educated at home and the Christian orthodoxy and beliefs about the origins of life and species of their parent-teachers. Professional educators have strong concerns about whether untrained parents can provide their children with adequate science instruction in a home school environment. Some research suggests that strong religious beliefs, which exist among most home school families, may interfere with academic success of students. Science educators are interested in the scientific literacy of all students, including the public, private, and home schooled. Limited research shows that the home educated do well in terms of science achievement and cognitive development. It is not clear whether logical and research-related concerns about science education in the home school, particularly the highly religious one, are well founded. This study is an exploratory attempt to clarify some of the confusion and to determine whether significant relationships exist between parents' beliefs and their home educated students' science achievement. A questionnaire with a religious belief subscale and a belief about origins and life subscale was developed. The subscales were developed in a manner to assure high validity and reliability. Approximately 293 families and 450 home school students were involved in the study. Parents responded to the questionnaire items on beliefs while students were tested using the Stanford Achievement Test. Correlation analysis was performed. The findings suggest that the home educated do well in terms of standardized achievement tests of science learning, and parents' religious beliefs and beliefs about origins do not significantly impact their students' science learning as measured by such tests. Strong concerns about science education in home schools, particularly religious ones, are possibly allayed by these findings. This study and others in the area of home education may begin to shed light on the learning of science in the home school environment and what factors do or do not contribute to these students' science learning success. Suggestions about what science educators might learn from home education and about how science educators might help home schoolers are made.

THE SCIENTIFIC THEORY PROFILE: A PHILOSOPHY OF SCIENCE MODEL FOR SCIENCE TEACHERS

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A model was developed that depicts current positions in philosophy of science on the nature of theories. It can be used in a course for prospective or practicing science teachers. First, a thorough justification for including philosophy of science in teacher education was given followed by a seventeen-institution survey of the extent of this approach. Results from the survey indicate little commitment to a philosophy of science approach. Attention to this broader concern occurs during a methods course. Ten recent methods texts were evaluated with the finding that only one emphasizes adequately a post-modern philosophical treatment. The other texts either lack adequate coverage or have inaccurate descriptions. The model developed for use with science teachers -- called the Scientific Theory Profile -- consisted of placing three well-know philosophers on an x- and y-axis based on their methods for justifying theories (rational versus natural) and their views on scientific theories as the Truth versus models of what works best (realism versus anti-realism). The assumption is that individuals have different degrees of commitment to these views and seeing this range of views would help clarify current understandings about science. The philosophers selected for detailed analysis who form the keystone positions in the model are Thomas Kuhn, Sir Karl Popper and Carl Hempel. Nine other philosophers, all influenced by the three originals, are included in an analysis of less detail, their positions begin added to the Scientific Theory Profile. The Scientific Theory Profile then forms the basis for an outline of a course in philosophy of science for science teachers, with a defined mission, course goals, terminal performance objectives and enabling objectives. Each enabling objective is augmented with suggested concepts and activities -- all to improve science teacher understanding of the current interpretations in philosophy of science regarding scientific theories. The results of this study should point science teachers towards more accurate perceptions of what science is and what it is not, of the unique and diverse roles theory plays in science, and of the dynamic way science is conducted with elements of art and serendipity, as well as tenacity and "good" science.

THE USE OF CONCEPT MAPPING IN SCIENCE EDUCATION RESEARCH: OVERVIEWS AND ISSUES

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The December 1990 issue of the Journal of Research in Science Teaching was a special on entitled: Perspectives on Concept Mapping. It therefore seems timely to assemble a panel to discuss "The Use of Concept Mapping in Science Education Research--Overview and Issues" at the 1991 NARST Annual Meeting. Each of the panel members were invited to participate in this session has used concept mapping in his/her research and is the author of an article in the special issue. Geographically, the panelists represent science education research activity in the East, South Atlantic, Midwest, West and Deep South regions of the country. Each of the participants will present a concise overview of his/her new JRST article on concept mapping and will raise issues based upon that work. Special attention will be given to concept mapping as : (a) a cartography of cognition (b) a semantic network, (c) a tool for exploring conceptual change, (d) a heuristic for curriculum development, and (e) a basis for further research. By raising important issues, providing multiple viewpoints, and suggesting future research, the panel seeks to clarify what is currently know and to identify what needs to be known about this theory-based metacognitive strategy.

WHAT COUNTS AS SUCCESS? PERSPECTIVES FROM PRACTICE AND RESEARCH

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Part of the folklore of teaching is that teachers' actions are driven by what "works" in their classrooms. However, "what works" can be defined in a multitude of ways depending on what the teachers are trying to achieve and how they decide if their goals have been reached. This study clarifies the goals of two experienced high school chemistry teachers and examines how they decide if their goals have been reached. Data sources include over 75 classroom observations and 30 hours of interviews with the teachers concerning their instruction. The goals and evaluative criteria of these teachers are then contrasted with those that are often used by science education researchers. Interview questions directed at instructional purposes led to a multitude of responses. The purposes included for students to do the following: (1) understand particular chemical concepts, (2) improve mathematical ability, (3) improve lab skills, (4) improve or practice in working with other people, (5) improve writing skills, especially scientific writing skills, (6) improve reading skills, (7) develop skills in reading and creating charts and graphs, (8) build relationships between teacher and student, (9) connect chemistry content with the world outside the classroom, (10) enjoy learning chemistry, (11) learn the value of hard work, and (12) learn to be responsible. To assess whether they had reached these goals the teachers gathered information based on what was readily observable. Immediate student reaction (e.g., on-task behavior, cues indicating interest) was critical in assessing whether the instruction was working. Many of their other goals, however, they concede to be difficult to assess. When these teachers were asked what they were trying to accomplish and how they knew if they accomplished it, they described a complex array of goals, many of which are difficult or impossible to measure directly. This becomes interesting when we examine how narrowly researchers define what counts as a success. Research studies of effective instruction typically focus on one or perhaps two well-defined, preferable measurable variables to determine if the instruction worked. As researchers we need to give more attention to the fact that teachers do not define their work as narrowly as we define it. When we examine the prospects of better integrating research and practice, we would be wise to consider the complexity of teachers' goals so that we can be more useful in working with teachers to decide what works and what does not.

THE NATURAL WORLD AS UNDERSTOOD BY SELECTED COLLEGE STUDENTS: A WORLD VIEW METHODOLOGICAL EXPLORATION

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As other studies have indicated world view variations potentially interfere with science education, particularly when instruction proceeds unaware of the importance of fundamental epistemological structure in learning (Cobern, 1990). The research we reported addressed the fundamental question: What do students believe about the world around them? The research specifically addressed the cognitive culture of college students with respect to nature, a delimitation on the total world of students. The investigation was an exploratory investigation in uncharted waters, and thus an equally important objective was to test the effectiveness of the ethonographic methods employed. This research embarked on an avenue that is a natural extension of the science education research that has been evolving over the last twenty years. Though rooted in neo-Piagetian research, constructivism is a departure from the mainstream. Furthermore, a contextual constructivist branch of research has emerged for the more personalistic constructivist departure from neo-Piagetianism. This evolutionary process ought to naturally culminate in cultural research, where culture includes cognitive culture as well as social and material culture. The approach to cultural study taken in the current research involved the use of logico-structuralism, a world view model adapted from cultural anthropology. The subjects of the study were 20 college students enrolled in a science course. Data was collected via semi-structured ethonographic interviews. The structure came from projection devices used to encourage the participants to talk about the natural world. The analysis of interview transcripts followed a grounded theory format. This process led to inferences about students' fundamental views toward the natural world. For example, many of the students' knowledge about nature was considered important. However, this was not the knowledge of the detached observer, but experiential knowledge. Several students did not connect knowledge of the natural world with science. Many of the students had a strong aesthetic sense about the natural world. They preferentially understood nature in terms of beauty and design. These students also had a strong sense that nature must be conserved. Finally, these students generally viewed the natural world as orderly. Techniques involved worked well as attested by the eagerness of students to comment on and discuss issues raised in the interviews. The projection devices were found to function well in that the students largely confined their discussion to the topic of the natural world and there was a convergence of comments in response to the different projection devices. The findings are of interest. If the science classroom is anything like that suggested by some research (e.g., Kolbourn, 1984; Tobias, 1990), then there is indeed a mismatch between many students' views of the natural world (e.g., aesthetic) and the view presented in science education (e.g., materialistic). The extent of the student beliefs noted here and whether such a mismatch as those beliefs imply is of much consequence will undoubtedly be the subject of further research.

ASPECTS OF COGNITIVE APPRENTICESHIP IN SCIENCE TEACHING

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Recent reports about American schools have indicated the need for improvement of science teaching and learning. One of the solutions advocated calls for classroom contexts that allow for authentic practice under the guidance of teachers who model pertinent skills as practitioners in the field of study. The metaphor used to describe such teaching-learning situation is that of cognitive apprenticeship: teachers model scientific skills and coach students in their attempts to handle the practical and conceptual tools in the sciences. This paper summarizes the results of a two-part study. During the first part, we looked at the learning outcomes when grade 8 students, in small groups of 2 and 3 individuals are framing, developing, and completing their own research agendas. The second part of the study reports on the interactions between small numbers of students (103) and a teacher who acts as a practitioner and coach. An interpretive research methodology was used in both parts of the study. Underlying the study was a constructivist view of knowledge acquisition. The findings of the study are based on direct observations of teachers and students; on interviews with teachers and students; on audio-taped sessions of tutoring relationship; and on interviews with the tutee in the relationship. The findings of the two-part study will be discussed in the form of four assertions. These are, (1) the students engaged in and developed sustained research programs that showed high levels of sophistication; (2) supported by the increasingly familiar context, the students developed a wide variety of complex research and analysis skills; (3) the students constructed new means of representation and new vocabulary to talk about and report the results of their research; and (4) in small group and one-to-one interactions, the three components of cognitive apprenticeship (modeling, coaching, and scaffolding/fading) promote successful, higher-level cognitive learning. The results of this study confirm the viability of the concept of cognitive apprenticeship for science learning and teaching. The discussion will address the issue of helping teachers to change their strategies through a change of metaphors and will address the issue of research based in and conducted from the school level.

NEW DIRECTIONS FOR RESEARCH IN PHYSICS EDUCATION

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The presenters in this Symposium will have participated in a Workshop on Physics Learning that will be held in Bremen, Germany in March 1991. The overall aim of the Bremen workshop will be to orient physics education research towards the investigation of learning processes that lead to a deeper and more robust understanding of physics. The presenters will discuss empirical and/or theoretical issues regarding some of their own current research, will expand on relevant issues that emerge at the Bremen workshop, and will also comment on directions for future research. The first speaker will give an overview of the Bremen workshop, for which he is co-director. He will describe significant issues that emerged in the workshop discussions, including an agenda of issues that might guide future research in physics learning. The presenter is a physicist by training, who has carried out empirical investigations of student understanding in different domains of physics for the past seven years. Currently he is using computer-videodisc technology to facilitate student learning in the domain of optics. The second speaker has 18 years experience in science education teaching and research. He has carried out extensive theoretical and empirical research on issues of conceptual change and has designed and implemented conceptual change instruction for high school and college level physics students. In his presentation the speaker will present an analysis of the meaning of the status of a student's conception, will examine different methods of determining status, and will discuss the outcomes of these activities. The third speaker is a secondary school physics instructor whose work for the past decade has focused on improving the instructional system by taking students' conceptions and reasoning into account. His presentation will outline three aspects of his current research work: (1) Theoretical base for investigations of students; learning processes, in which he has identified "facets" of knowledge that students seem to use in constructing responses to questions about physical systems; (2) Teaching strategies that emphasize elaboration in classroom dialogues and in problem solving; and (3) Instructional principles for curriculum design for fostering development of conceptual understanding.

A QUALITATIVE ANALYSIS OF PRESERVICE ELEMENTARY TEACHERS' CONCEPTIONS OF HEAT TRANSFER AND TEMPERATURE

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The purpose of this study was to determine the level of understanding concerning heat transfer and temperature held by preservice elementary teachers. Three questions were identified: (1) What did preservice elementary teachers know about everyday phenomena that involved heat transfer and temperature? (2) How did their answers compare with answers accepted by most experts as being correct? (3) How did their answers compare with answers given by elementary students as reported in the literature? Eleven elementary education majors from an midwestern university elementary methods class were interviewed using an interview-about-instances technique. Interview transcripts were analyzed using a variety of matrices. Frequent peer reviews and member checks were made to insure the validity and consistency of the findings. Detailed descriptions of the setting, methods, and the findings were provided to accurately represent the multiple realities. The following conclusions were made based on the results: (1) The conceptual model of heat transfer and temperature used by the subjects in the study more closely resemble the caloric theory than modern thermodynamics; (2) the problem-solving method employed by the subjects consisted largely of recalled facts and personal experiences. The subjects were unable to deal successfully with interactions between two or more variables; (3) The idea of temperature as a relative measure is well-developed in the subjects but does not appear to be grounded in the kinetic theory of matter; (4) The conceptions held by the subjects matches closely with those reported being held by older elementary children. The findings of this study suggest that alternative methods should be employed in teaching science to future elementary teachers. The methods might include making them aware of their current conceptions before providing them with activities to change any incorrect conceptions they may have.

THE IMPLEMENTATION OF EQUITABLE TEACHING STRATEGIES BY BIOLOGY STUDENT TEACHERS

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Teachers can perpetuate stereotypic cultural beliefs regarding girls' ability in, aptitude for, and suitability for science by their teaching practices and behaviors. As teachers have a major influence on girls' career choices, their equitable teaching practices in the classroom are important to encourage all students, but especially girls, to continue with science. Researchers have studied science classrooms and have defined common strategies and practices that can help create an equitable classroom environment. The purpose of this study was to determine if high school biology student teachers could transfer learning equitable teaching strategies to actual teaching and the support conditions necessary for that transfer. Two support conditions were assessed: cooperating teacher and peer group support. Seven student teachers were placed into three groups. One group had both support conditions, the second group had only one condition (peer support), and the third group did not have either support condition. Both qualitative and quantitative data sources were collected. Results showed that preservice teachers could transfer learned equitable teaching into actual teaching practice. However, they were more successful in achieving the transfer if they were supervised by cooperating teachers who are sensitized to the issue of gender equity in education. Being involved in a peer support group was not as crucial to using the strategies as having a supportive cooperative teacher.

CONSTRAINTS TO TEACHING ELEMENTARY SCIENCE: A CASE STUDY OF A SCIENCE ENTHUSIAST STUDENT TEACHER

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Science is a neglected subject in U.S. elementary schools; most elementary school teachers feel unqualified and uncomfortable when asked to teach it. But what becomes of those few teachers who are enthusiastic about teaching science? What constraints face them and how do they teach science within these constraints? This case study of one elementary school teacher attempted to answer these questions. Marie was known among elementary education faculty as a science enthusiast. She had taught at science days in local schools and during summer institutes, participated in environmental education workshops, and expressed a desire to be an elementary science specialist. In order to examine the transition from university student to student teacher of this beginning teacher, I became a participant observer in her fourth grade class of the 9-week student teaching experience. During this time I observed the 45-minute science period which took place four mornings a week. The data sources for this project were (a) field notes taken during observations, (b) transcripts of interviews with Marie, her cooperating teachers, students, and the principal, and (c) documents including lesson plans, class handouts, and tests. Data analysis consisted mainly of inductive analysis in which repeated examination of these data sources led to the development of categories for organizing data. We also generated assertions and tested their validity by triangulating the various data sources. From the data we have complied a picture of Marie's vision of teaching elementary school science, including her views on inquiry, textbooks, and group work. Furthermore we have developed assertions about the constraints which Marie perceived as she attempted to implement her vision: expectations from the cooperating teachers and the university supervisors, the school's status-quo for science teaching and classroom management, limited resources, lack of content and pedagogical knowledge, and assessment of students. Finally from the data we have inducted a number of coping patterns which Marie knowingly and unknowingly used to address these perceived constraints. The findings of this study have implications for the current reform movement in science education. To implement reforms we must take into account the position of the preservice teacher, negotiating idealistic beliefs about science teaching within the existing school structure. This study establishes a data base from which we can begin to understand the science enthusiasts among prospective teachers who will change science education in our elementary schools.

AN ANALYSIS OF METACOGNITIVE SKILLS UTILIZED BY STUDENTS DURING COMPUTER SIMULATION ACTIVITIES

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This research study analyzed students' interactions to computer programs to assess their meta-cognitive skills. The meta-cognitive skills assesses were: (1) planning a course of action; (2) monitoring the outcomes; (3) evaluating data collection strategies; (4) thinking about or listing alternative strategies; (5) revising strategies; (6) prioritizing actions. The research questions addressed were: (1) What are the initial procedures used by students to solve the explained problem? (2) Do students monitor their results to change their strategies and the program progresses? (3) Do students choose differing metacognitive strategies based upon the characteristics of the computer program or upon their recorded actions? (4) Is a change in the meta-cognitive strategy influenced by prior success or failure at a computer simulation task? The participants who were students in grades 7-12 were observed individually or in pairs during their work on specific programs. The programs utilized are all public domain and are called Magic Mirrors, Funny Numbers, and Animals. The participants were observed during each interaction and a record was kept of their verbal behavior and of their computer responses. Based upon these observation, it was concluded that students do exhibit differing metacognitive behaviors. The behaviors are not dependent upon their age or grade level. Students do not readily change their metacognitive process if another one has proven to be initially successful. Students are more capable of monitoring their cognitive processes when they receive some type of feedback, either from the computer or from other persons involved in the activity. This research is exploratory in nature and is designed to build a foundation for the analysis of both qualitative and quantitative data. It may lead to the development of computer software in science that requires students to more closely monitor their actions. It may also help to focus future research on relevant cognitive skills variables.

DEVELOPMENT OF COMPUTER SOFTWARE FOR DIAGNOSIS AND REMEDIATION OF ALTERNATIVE DYNAMICS CONCEPTIONS: A PROBLEM IN INSTRUCTIONAL DESIGN AS WELL AS IN SCIENCE CONCEPTUAL CHANGE

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Several concerns relative to research on conceptual change are: (a) how to diagnose alternative conceptions, where the traditional methods of needs assessment and evaluation of learning do not find them; (b) how to facilitate the restructuring of alternative conceptions, where traditional instruction does not do this; and (c) how to evaluate change in alternative conceptions, where traditional instruction does not even detect their existence. The problems do not appear to be exclusively one of conceptual change or instructional design, rather, an interaction between both. A model was developed to instructionally elicit a student's alternative conceptions in science and select software design ingredients to allow a stand-alone microcomputer system to supplement traditional science instruction by diagnosing a student's alternative conceptions, facilitating their alteration, and posttesting for any changes in the conceptions. This model was implemented with a representative sample of 8th grade physical science students. Sixty students (termed completed students) had studied force and motion in their science classes 2 and 6 months earlier, respectively. The thirty-six students (termed in process students) were currently studying force and motion. When alternative conceptions were detected, the system presented two simulations which were designed to facilitate the student's alteration of one or more of these naive conceptions. Evidence of immediate change was determined by administering the computer posttest both to completed students who had worked the simulation and to completed students who had not. Evidence of the student's retention of simulation-elicited changes was assessed 1.5 months later by: a) readministering the posttest on the computer or pencil-and-paper to a sample of those completed students who had worked the simulations; and b) giving structured interviews to another sample of completed students who worked the simulations. During the interviews, given to only a sample of students, pictures were shown to the student, and they were asked to describe what they thought was happening in the picture and to explain why it was happening. Completed students exhibited a very different pattern of non-scientific answers on the computer diagnostic test than did in-process students currently studying that topic. These "error profiles" indicated that many students possessed more naive conceptions at the beginning of the study of the unit on force and motion than after completing the unit. The microcomputer diagnosis-and-remediation system apparently put sufficient emphasis on the individual needs that the students were diagnosed as possessing alternative conceptions several months after studying force and motion. The computer system utilized the science conceptual change model and teaching strategies such that working through the simulations did facilitate in altering students' conceptions to a significant degree. The computer posttest supplied evidence of the students' short-term conceptual change, and the retention test 1.5 months later supplied evidence of robustness of the conceptual change.

THE DEVELOPMENT AND PRELIMINARY EVALUATION OF ANCHORED INSTRUCTION ENVIRONMENTS FOR DEVELOPING MATHEMATICAL AND SCIENTIFIC THINKING

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A major goal of anchored instruction is to allow students and teachers to experience the kinds of problems and opportunities that experts in various areas encounter. Theorists such as Dewey (1933), Schwab (1960) and N.R. Hanson (1970) emphasize that experts in an area have been immersed in phenomena and are familiar with how they have been thinking about them. When introduced to new theories, concepts and principles that are relevant to their areas of interest, the experts can experience the changes in their own thinking that these ideas afford. For novices however, the introduction of concepts and theories often seem like the mere introduction of new facts or mechanical procedures to be memorized. Because the novices have not been immersed in the phenomena being investigated, they are unable to experience the effects of the new information on their own noticing and understanding. An example of an anchored instruction is a project being conducted by the Learning Technology Center, initially sponsored by the James S. McDonnell Foundation and now currently receiving National Science Foundation support. It is designed to develop and evaluate a series of videodisc adventures whose primary focus is on mathematical problem formulation and problem solving. Several situations exist within the two current Jasper episodes that could provide specific anchors to science instruction. For example, in episode one a decision was made in the design phase of the disk to embed information about two specific science concepts that are often taught at the target grade levels of the disk, simple machines and flotation. Additional examples of how the anchored instructional model has been used in science instruction include the short video presentation titled the "Golden Statuette", which also uses a short story to help students begin to see the usefulness of such concepts as density and other prototype science video segments being produced for a "Scientists in Action Series". The need to provide experiences with complex examples of problem formulation is illustrated by data from 6th graders. Although these students had scored above average on standard mathematics achievement tests, they were extremely poor at problem identification and formulation. However, the data also indicate that fifth grade students can become very good at complex problem formulation on tasks similar to Jasper after working with Jasper in cooperative learning groups for 4 to 5 class sessions.

MAKING SENSE OF SCIENCE AND SCIENCE TEACHING: THE DECONSTRUCTION OF KNOWLEDGE AMONG PROSPECTIVE ELEMENTARY TEACHERS

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This proposal describes part of an ongoing research project aimed at developing a grounded theory for elementary science teacher education. The main emphasis of the research is to determine the content of the knowledge prospective elementary school teachers use when they are planning for and implementing science lessons. Patterns of ideas to which the prospective teachers refer when planning and implementing lessons have been found: 1) prospective elementary school science teachers believe that their role in a science class is to tell students what they need to know; 2) prospective elementary school teachers believed that the "hand-on" approach to science learning is the optional method of teaching science; 3) prospective elementary school science teachers refer to an implicit set of beliefs when planning and implementing science lessons which may differ from more explicit beliefs; 4) planning for student control and management dominates lesson construction and; 5) affective concerns, such as fostering student self esteem are also major referents. However, these prospective elementary school science teachers do not believe that elementary science is that which is in the textbook and that which is in the state standards. Interpretations of questionnaire data about the nature of science, the nature of teaching, and the nature of learning are also reported. Many of the major beliefs or referents which prospective teachers hold have both been thought of in an explicit way. Activities in the teaching and learning course have encouraged the prospective teachers to reflect on their implicit beliefs to make them explicit. Changes in thinking patterns are noted. Direct and substantial implications for elementary science teacher education courses are made.

FROM SCIENCE STUDENT TO SCIENCE TEACHER: PROSPECTIVE TEACHERS MAKING SENSE OF SCIENCE TEACHING

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By the time prospective science teachers reach the point in their education that they begin to take science education courses they are often seniors expecting to begin their student teaching experience within the academic year. They have spent more than two years taking courses in the various fields of science and often believe such courses represent science as it should be taught. They have spent as much as seventeen years as students in formal education settings, but as prospective teachers they have given little thought to pedagogy or epistemology; they often have never asked the question - how is it that people come to know what they know? This paper is an attempt to understand what prospective teachers have constructed about teaching, learning, and the nature of science and how they make sense of these concepts as they move from being a science student to a science teacher. The data from this interpretive study was interpreted from a constructivist epistemology and theories from cultural anthropology. The following assertions emerged from the study: 1) Prospective teachers' beliefs about science and science teaching was constructed from experiences in university science classes. 2) Based on their own personal experiences, prospective teachers believed that high schools science should be taught to prepare students for college science. These two beliefs underlie the prospective teachers' notions of teaching practice that emphasized lecture and confirmatory laboratories in the high school science classroom. 3) Prospective teachers believed that science education courses are survival guides to first year teaching. These beliefs created conflicts in the minds of prospective teacher during their science education coursework where such beliefs were not valued.

THE INFLUENCE OF PRESERVICE SECONDARY SCIENCE TEACHERS' BELIEFS ABOUT SCIENCE AND PEDAGOGY ON THEIR PLANNING AND TEACHING

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In the past decade, research on teacher education has been shifting from the emphasis on changing teachers' behaviors to investigating how teachers' mental thinking influences their teaching behaviors. Teachers' beliefs and planning are two important components among teacher thinking research. However, the research focused on the areas of either elementary schools teachers, experienced teachers, or clinical settings. Few Fewer studies have focused on preservice secondary science teachers and their beliefs on how science and pedagogy influence their planning and teaching in a natural setting. The purposes of this study are: first, to uncover preservice secondary science teachers' beliefs about science and pedagogy, and second, to investigate how preservice science teachers' beliefs about science and pedagogy influence their planning and teaching. This study used qualitative methods such as participation observation, field notes and in-depth interviews. The primary participants in this study were three prospective secondary science teachers, enrolled for the winter and spring quarters of the 1988 academic year in the secondary science methods class and in student teaching assignments at a southeastern university in the U.S. Topics touched on in the interviews included the ways informants planned their lessons, the considerations during their planning, the resources they used in planning, and the reflection on their teaching performance. Three informants were also observed during their student teaching. Two researchers observed each informant's classroom teaching once a week for eight weeks. Post conference interviews were conducted right after each observation session. Interviews with the individuals' cooperating teachers and college instructors served as supplementary data to provide triangulation on data sources. All the interviews were audio-taped and then transcribed verbatim. An open-coding system was generated to analyze data, at the same time, codes were constantly revised and then categorized the data into categories. Direct quotes and assertions would be incorporated into each category. The study found that the three secondary preservice science teachers have articulated similar beliefs about science, students, teacher's role, teaching, and learning. However, the context and meaning behind their words have subtle differences, which also influence their action during planning and teaching. The findings of this study also indicated that student teachers' beliefs influence their planning and teaching behaviors. However, the complex nature of belief systems makes the relationship between beliefs an actions difficult to predict. On the other hand, although preservice secondary science teachers hold a variety of beliefs about science and pedagogy, not all the beliefs they articulated influence their planning and teaching. Which beliefs would dominate teachers' actions depend on the situation. In the end, suggestions for science educators are also provided.

THEORETICAL BASES FOR SCIENCE EDUCATION RESEARCH

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Perspective on the nature of science and science learning are guided by many theoretical bases. As science educators do research, it is very important to identify and follow a theoretical line that can be recognized and tested by fellow researchers. At no time in the history of science education research has there been as much activity in using history and philosophy of science, various social sciences including psychology, sociology, and anthropology, and other disciplines to bear on our own discipline of science education. It is ironic that as nearly all science education researchers board the "constructivism express", we are searching in so may different areas for better means to make sense of science learning. Perhaps it is a sign that we are finally shaking the simplistic bonds of behaviorism/positivism and recognizing the complexity of science education. The nature of the enterprise called science is complex and science education is much more complex since knowledge of the social sciences must be combined with knowledge of the natural sciences. It is very important to recognize the enormous complexity involved in gaining a better understanding of science learning in the many contexts that can and do exist. The importance of context in science and science education cannot be over-emphasized, nor can the importance of developing clear theoretical bases on which research in science education can be tested. Underestimating the complexity of knowledge restructuring in science education yields simplistic solutions for improving science curricula and instructional methods. Researchers in science education must help to identify strategies that science teachers and their students can use to better achieve the goal of conceptual change. On key to understanding how to help students construct knowledge that is more compatible with scientists' knowledge of nature is determining what counts as important evidence in the mind of the learner. Without this knowledge, science teachers are much less likely to experience success in helping students construct conceptual frameworks that are more compatible with scientists' knowledge of nature. The nature of knowledge varies across the different contexts that we call science disciplines. Contexts within and across the natural sciences vary as do the contexts within and across the social sciences. Ways of knowing depend on what is to be known, as Ernst Mayr has shown so well within biology. Ways of knowing for the evolutionary biologist differ for the molecular biologist, just as ways of knowing for the anthropologist differ from the psychologist. Recognizing this complexity in the natural and social sciences will help science educators better understand the importance of context in studying the learning of science.

INTENTIONS OF GRADE 5-8 SCIENCE TEACHERS TO USE SCIENCE INVESTIGATIONS: APPLICATIONS OF THE THEORY OF PLANNED BEHAVIOR

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To what degree do teacher participants in one science enhancement institute intend to use the information in the classroom the next fall? What factors assist this extension of learning? What factors detract from teachers applying new knowledge in the classroom? Fifteen 5th-8th grade South Dakota science teachers from a physical and life science enhancement summer institute participated in a study to apply the social science "Theory of Planned Behavior" to an education setting. The study centered on the teachers intentions to use the knowledge gained from the institute in their 5th-8th classrooms. Earlier applications of this theory to education by Crawley indicated that the intention to perform a specific behavior was within the control of teachers, and that teachers in his research needed little social support as long as there were resources and sufficient opportunity to perform the behavior. The goal behavior for the participants was to "teach two investigations from the institute in the classroom before October 8th, 1989." Using tenants of the Theory of Planned Behavior, an open-ended questionnaire identified participants salient beliefs relating to personal outcomes, personal support, and personal control. Results of the open-ended questionnaire were content analyzed and rewritten to reflect the participants belief statements. Closed questionnaires were developed to learn more about teachers' intentions to use their investigations in their classrooms. Regression analysis was employed. Qualitative data, including personal interview and a demographic survey enriched the results of the closed questionnaire. Gains in participants' science content knowledge was statistically significant, and overall science attitude of participants was high, according to the "Attitudes, Preferences and Understanding Survey" administered to the participants. The Theory of Planned Behavior was shown to have utility in identifying the intentions of teachers to use inservice information toward improving classroom practices.

HISPANIC STUDENTS' ATTITUDES TOWARD ENROLLING IN HIGH SCHOOL CHEMISTRY: A STUDY OF PLANNED BEHAVIOR AND BELIEF-BASED CHANGE

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The purpose of the study was to (1) identify the determinants that motivate Hispanic students to enroll in an elective high school chemistry course and (2) determine if providing information to students and their parents/guardians that addresses students' concerns about chemistry enrollment results in more students registering to enroll in chemistry. Ajzen's Theory of Planned Behavior provides a model for understanding the rational decision-making process and served as the theoretical basis for the study. Sixty-nine grade 10 students completed the Chemistry Interest Survey (CIS), a 9-item, open-ended questionnaire, in the late Fall Semester, 1989. Student responses to the CIS were content analyzed, resulting in a final set of beliefs (and referents) called modal salient beliefs (or referents). Information about students' salient beliefs and referents was used to construct items contained on the 50-item Chemistry Interest Questionnaire (CIQ), the primary data collection instrument, and audiotaped messages and accompanying information sheets for both students and parents/guardians. Messages contained information that reinforced favorable beliefs and either downplayed or discredited unfavorable beliefs that students held about enrolling in chemistry in Fall, 1990. The messages were administered to one control and two experimental groups. Approximately one week after completing the "treatment" phase of the study, students (n=598) completed the CIQ, and shortly thereafter registered for courses for the Fall Semester, 1990. The findings of the study revealed that personal motivation combined with a sense of self-determination were significant predictors of chemistry enrollment. Personal attitude and a sense of personal control but not social support provided the basis for personal motivation, with personal attitude contributing much more to motivation than did personal control. Personal beliefs that contributed significantly to students' attitudes toward enrolling in chemistry included: reaching their educational goals, studying topics that are interesting, attaining their career goals, possibly getting low grades, increasing their knowledge about chemistry, and doing more work at home and at school. In addition, three major factors surfaced as primary contributors to students' sense of personal control affecting the decision to enroll in chemistry. Students also see speaking Spanish better than English and poor performance in math class to be barriers to enrolling in chemistry. Moreover, chemistry enrollment exceeded expectations for students receiving the "student only" message, surpassing that of the students enrolled in the control group. Differences in chemistry enrollment between "student only" and "student and parent/guardian" groups, though not significant tended to suggest the superiority of the "student only" message in improving chemistry enrollment.

THE EFFECT OF TWO VIDEOTAPED PERSUASIVE MESSAGES ON 7TH GRADE SCIENCE STUDENTS' INTENTIONS TO PERFORM AN AIDS-RELATED LABORATORY BEHAVIOR

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The purpose of this study was to examine the effects of two systematically designed persuasive communications for changing 7th grade life science students' intentions toward becoming the laboratory partner of a classmate who has AIDS. The theoretical framework on which the research rested was an integration of three cognitive response paradigms: the theory of reasoned action, the theory of planned behavior, and the elaboration likelihood model. The study compared the persuasiveness of arguments based on salient beliefs held by the message recipients with arguments based on traditional content-related facts pertinent to the message topic and tested the interaction of both ability and motivation to process message arguments with retention of intentional change. The study utilized a 3x2x2 factorial design, incorporating random assignment of intact classes to one of twelve treatment groups. Interest was focused on three experimental factors which also corresponded to the independent variables: Factor A was the type of construction used for each persuasive message; Factor B was the presence or absence of a mental focusing task; and Factor C was the subject's degree of prior knowledge concerning the transmission and prevention of AIDS. Subjects were 312 seventh grade science students from three Texas middle schools. An instrument designed to measure subjects' intentions, attitudes, subjective norms, and perceived behavioral control pertaining to the performance of the laboratory behavior in question was administered at pre, post, and delayed post intervals. Treatments consisted of the presentation of videotaped communication either with or without the added instruction to imagine and then explain a hypothetical situation involving a personal encounter with AIDS. Repeated measures analysis of covariance showed a highly significant difference among adjusted means for the three message types at delayed posttest, indicating that only message arguments based on recipient salient beliefs were capable of producing sustainable intentional change. Focusing task and degree of prior knowledge by time interactions offered some support for the proposition that increased motivation and ability to process message arguments leads to the maintenance of such change, but only under certain conditions. Apparently, the combination of high degree of prior knowledge and the presence of a focusing task interfered with the thoughtful consideration of issue-relevant arguments; while a focusing task combined with low degree of prior knowledge supplemented the subject's lack of information concerning the message topic and thereby enhanced its elaboration.

PREDICTING AND UNDERSTANDING KOREAN HIGH SCHOOL STUDENTS' SCIENCE TRACK CHOICE: TESTING THE THEORY OF REASONED ACTION BY STRUCTURAL EQUATION MODELING

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This study aims at predicting and understanding Korean high school students' track choice for college entrance. To this end, the study adopted the theory of reasoned action (TRA) proposed by Fishbein and Ajzen for its theoretical framework. The study involved 665 first year high school students from four representative regions of Korea. The survey instruments were questionnaires developed by the author under the guidance of the TRA. The questionnaires measured students' behavioral beliefs, outcome evaluations, normative beliefs, motivations to comply, attitudes, subjective norms, and intentions to represent the theoretical constructs of the TRA. The behavior of interest in this study was Korean students' choice of the science track when they completed the track application forms during the first year of high school. External variables such as students' self-concepts about their performance in science-related subjects and demographic variables were also gathered. To answer the research questions the study adopted regression analyses and the structural equation modeling with LISREL, a computer statistical program developed by Joreskog and Sorbom. Major findings of the study are as follows: (1) with minor modifications, the TRA was applicable to the prediction and understanding of Korean high school students' track choice; (2) track choice was mainly under the students' volitional control, and intention was mostly a function of personal preference; (3) subjective norm had a small but direct influence on behavior; (4) subject norm did not have a direct influence on intention, its influence seemed to be mediated by attitude; (5) among the external variables, gender and self-concept of performance in science, math, and in academic courses in general were related to track choice; boys preferred the science track, girls preferred the humanities track; (6) parents were most influential on students' track choice; and (7) future career aspirations commensurate with students' aptitude was the most important incentive for choosing the science track. However, perceived difficulty of courses turned students away from the science track. Implications of these findings are drawn and recommendations are made for science teachers to improve science education and to attract more students to the science track. Recommendations for future researchers are also presented.

STUDENT AND PARENTAL MESSAGE EFFECTS ON URBAN HISPANIC STUDENTS' INTENTION TO ENROLL IN HIGH SCHOOL CHEMISTRY

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This research, inspired by the recent concern for the underrepresentation of Hispanics in science and science-related careers, is a posttest-control group experimental study focused on the effects of belief-based messages, (1) to students-and-parents and (2) to students only, on the enrollment intention of Hispanic students in their first elective science course at the pre-college level, chemistry. The investigators, using well-established social psychological theories of persuasion (Petty and Cacioppo, 1986) and planned behavior (Fishbein & Ajzen, 1975; Ajzen& Fishbein, 1980; Ajzen & Madden, 1986), examined the effects of the presentation of a message based on the behavioral, social and control beliefs of Hispanic students considering their option of enrolling in chemistry. The belief-based anecdotal message was presented under the central-processing-route principles of the elaboration likelihood model (Petty and Cacioppo, 1986). Responses to a belief-based questionnaire yielded direct measures of intention, attitude, subjective norm, and perceived behavioral controls and their antecedents, which data was compared by analysis of variance. Multiple, simple and stepwise regression analyses indicated the relative influence of factors in the path analysis of the model's linear chain of antecedents to intervention. When students only received the message, treatment vs control comparisons by ANOVA showed no significant difference. On the other hand, when both students and parents received the message, a significant difference in behavioral intention ($p=.0095$), subjective norm ($p=.0012$) and perceived behavioral control ($p=.0263$) was noted.

WHAT HAPPENS DURING HIGH SCHOOL CHEMISTRY LABORATORY SESSIONS? A DESCRIPTIVE CASE-STUDY OF THE BEHAVIORS EXHIBITED BY THREE TEACHERS AND THEIR STUDENTS

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The purpose of this study was to use qualitative research methodologies to answer two research question: (1) What do high school chemistry teachers and their students typically do during laboratory sessions? and (2) What is the relationship, if any, between teacher behavior and student behavior as exhibited during laboratory sessions? Three teachers, known here as Ms. Walen, Mr. Allan, and Mr. Roger, and one intact chemistry class for each, consented to participate in the study. As specially designed systematic observation instrument, the DALI, (DeCarlo Assessment of Laboratory Interactions) was used as the major data-gathering device. This instrument was used to code 2,076 student behaviors and 132 teacher behaviors as they were displayed during 14 laboratory sessions. The analysis of the data showed that the teachers, especially Ms. Whalen and Mr. Roger, displayed a consistent set of behaviors, or teaching style. Ms. Whalen was most frequently coded as exhibiting interactive behaviors with her students, either in a directive way (telling them what to do or how to do it, answering students questions), or in a social way (talking with students about issues unrelated to the laboratory activity). Mr. Roger consistently displayed behaviors that were coded as "unengaged" (grading papers, reading professional publications, tinkering with the computer, etc.) Mr. Allen's behavior varied somewhat from lab to lab, but he most frequently displayed the behaviors of "socializing" and "unengaged"). None of the teachers were ever coded as exhibiting a "stimulating" behavior such as asking questions of students or requiring students to think about their procedure or results. In regard to teacher behavior, it was concluded that each chemistry teacher in this study exhibited a relatively consistent repertoire of behaviors during laboratory activities regardless of the nature or topic of the lab. In regard to student behavior, it was concluded that students' behavior was largely focused on procedural aspects of the lab. From the results obtained in this study, one could not conclude that there is a cause-effect relationship between teacher behavior and student behavior during laboratory activities. Rather it appeared the perhaps student behavior during laboratory activities was dictated by other factors such as the teacher's classroom rules, grading procedures, or lab write-up requirements. In light of these findings it was suggested that it is each teacher's goals, beliefs, and instructional practices and behaviors, rather than the type or topic of laboratory activities, that will ultimately determine the value and effectiveness of the laboratory experience in promoting science content achievement, cognitive growth, positive attitude, and critical thinking.

EFFECTS OF CONTEXTUAL CUES ON STUDENT PERFORMANCE IN THE LABORATORY

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The results of laboratory practical exams often do not support the expectations proposed for laboratory centered instruction. Some factors which contribute to this dilemma are collectively identified here as contextual cues. Contextual cues are those aspects of content and the learning environment that students choose to assist them in making sense of laboratory activity. The question of interest was how do students respond to contextual cues to identify the appropriate procedures, collect key information, and explain findings. It was expected that the organization of materials would make either a positive or negative difference in student performance. After being classified according to their prior science experience and coursework, 60 "novice" and 30 "expert" preservice student teachers students were randomly assigned to one of two treatment groups and presented with organized or unorganized materials. All students completed two laboratory practical exams which were comprised of hands-on laboratory activities and short answer or multiple-choice questions. All students did their work by themselves and could not see others doing the same activity. Differences were observed between organized and unorganized treatment group means and evaluated using the Cochran-Cox t-test. For the novices, the organized group performed significantly better ($p<0.001$) when organizational cues were supportive while the unorganized group performed significantly better ($p<0.001$) when organizational cues were contradictory. No significant differences were found for either expert group on either activity. Decisions made by novice students seem far more influenced by material organization than expert students. Since expert students exhibited no such relationship, their prior experience and knowledge seems to have provided a stronger positive cueing effect.

A CONTENT ANALYSIS OF SECONDARY BIOLOGY LABORATORY ACTIVITIES

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The authors' purpose in this study was to examine the content of the laboratory activities of two popular high school biology textbooks. All of the laboratory activities from the BSCS Green Version and Modern Biology were analyzed using Task Section of the Laboratory Structure of Task Analysis Inventory (LAI). The task categories of the LAI parallel skills or behaviors which reflect scientific inquiry, problem solving skills, manipulative skills, and observational skills. Two judges were used in order to determine interrater reliability. It was discovered that neither text provides students many opportunities in developing problems, making experimental decisions, forming hypotheses, predicting results, interpreting and explaining procedures, and designing experiments. Both texts provide many opportunities for students to manipulate equipment, carry out observations, and deal with relationships. Neither text seems capable of meeting the goals of appropriate laboratory instruction as determined by a comprehensive review of the literature. Implications of the results on high school biology instruction are discussed.

THE RELATIONSHIP BETWEEN GENDER DIFFERENCES AND FIGURALLY PRESENTED ITEMS IN A THIRD GRADE C-R SCIENCE TEST IN COSTA RICA

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This study had two objectives: a) to determine differences in Science achievement among those third graders who took a C-R test with and without figurally presented items b) to assess gender differences among those third graders who took a C-R Science test and with and without figurally presented items. This study is part of a larger project on academic achievement in Costa Rica. The tests developed were criterion-referenced tests developed according to the two characteristics which differentiate these tests from non-referenced measurement instruments. First, the tests expect to measure a very well defined and specific content domain and second the results are interpreted in terms of the mastery of that content domain. The third grade science test consisted of thirty-six items which measured twelve objectives. Each objective, in turn, was measured by there items. All of these items were multiple choice items with four options. Two different forms of the test were assembled. The same items were used in the two forms; in the first form, all the information in the stem was presented in a short text plus a figure in all the items. The two forms of the test were given, at the end of the school year of 1988, to third graders of a national stratified sample, of elementary schools by region and school type. In each third grade visited 25% of the children took the science test. Spanish, Mathematics, and Social Studies tests were administered to the other 75% of the children. The text information form was given to the first child and the figure based information form to the second child and so on. A total of 1615 usable answer sheets were analyzed. From this total, 822 boys and 793 girls answered the tests. The text information form was administered to 809 children and the figure based information form to 806 children. ANOVAS were conducted in order to compare the two forms in each of the 12 objectives measured and were also used for the analysis of the total score. There were significant differences ($p = 0.05$) in nine of the twelve objectives. In all objectives but one, the highest means were obtained by the figure based information form. When the total scores were compared, the difference was also significant, in favor of the figure based information form. Gender differences were found in only three of the 12 objectives. These differences were presented for both forms, in the same three objectives. There were no gender differences in the total scores of the two test forms. It seems that Science items figurally presented influence Science achievement at the third grade level. These findings are important for the Costa Rican National Test Development Center and they should be made available to elementary school teachers in order to help them improve teacher made tests. These findings also seem to confirm previous results that revealed no gender differences on this dimension of figurally presented items.

THE DEVELOPMENT AND TESTING OF LABORATORY PERFORMANCE TASKS FOR THE ASSESSMENT OF ACHIEVEMENT IN HIGH SCHOOL PHYSICS

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The quest to stem "the rising tide of mediocrity" described in A Nation at Risk has prompted a myriad of changes in secondary science instruction. This increase in emphasis on "high quality" science instruction has prompted a great number of changes in science programs at both the local and state level. Appropriate assessments of these changes in curriculum are crucial to a meaningful evaluation of their effectiveness. Because the nature of many of the improvements has been to engage students in higher order thinking skills, simple paper and pencil tests are often ineffective as evaluation measures. Research has shown a much more definitive assessment of a student's ability to apply higher order thinking skills is possible with tests of performance in problem-solving tasks in a science laboratory. The Physics Laboratory Skills Test (PLST) was developed as a proto-type assessment instrument for evaluation of student ability to perform a range of process skills in the high school physics laboratory setting. The PLST included seven different items based on topics presented in a typical high school physics course. Each item constituted a separate laboratory performance test and was completed by individual students in a 40 minute class period. A sample of 219 physics students from rural, urban, public, and private schools in NY and PA were tested with the PLST in May 1990. Results of this study show that the PLST has usability, validity, and reliability as an assessment of basic skills (measuring and reporting) and higher order skills (planning and analysis). Participating teachers determined the PLST to be an appropriate and useful tool in evaluating individual student abilities. Content validity was established via evaluation by 'expert' high school physics teachers. The Pearson Correlation was used to verify construct validity ($r=.49$). Inter-rater reliability as measured by the Pearson Correlation was high ($r=.81$). The Cronbach Coefficient Alpha, which was used to determine internal consistency of each item yielded strong, positive results for the PLST. The outcomes of this study will be of particular interest to curriculum developers and classroom teachers, who prior to the development of this type of test, have been forced to operate without the normal feedback mechanism of testing. The PLST will help to close the loop and allow curriculum writers and teachers the opportunity to monitor and adjust their strategies to maximize their effectiveness. It is hoped that this type of practical assessment instrument will lead to a better understanding and appreciation of the unique learning opportunities endemic to the science laboratory.

CONSTRUCT VALIDITY OF MULTIPLE-CHOICE AND PERFORMANCE BASED ASSESSMENTS OF BASIC SCIENCE PROCESS SKILLS: A MULTITRAIT-MULTIMETHOD ANALYSIS

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Science process skills are described as a set of broadly transferable abilities, appropriate to all of the science disciplines and reflective of the true behavior of scientists. While science process skills have gained wide acceptance as an integral part of science curricula over the past 25 years, the development of valid and reliable instruments to assess those skills has lagged behind. Presently, few research instruments exist which measure science process skills, particularly the basic science process skills. Of the existing tests, few are adequately validated. Therefore, the purpose of the study was to gather evidence of the construct validity of the multiple-choice and performance-based versions of the Test of Basic Process Skills in Science (BAPS), the only research instrument designed to measure all of the most widely accepted basic science process skills for elementary and middle school students. A multitrait-multimethod construct validation technique was used to gather evidence of the convergent and discriminant validity of the BAPS tests. The technique requires the administration of the least two instruments, with different test formats, to measure a trait of interest, and at least two instruments, and again with different formats, to measure a different or discriminant trait. The BAPS multiple-choice test and the BAPS station test, a performance-based instrument, were used to measure the trait of interest, basic science process skills. The Test of Logical Thinking (TOLT) and the Bending Rods (RODS) Piagetian manipulative task were used to measure the discriminant trait, science reasoning ability. The four instruments were administered to a sample of 151 seventh grade students from a west Florida school district. The scores were then correlated and presented in a multitrait-multimethod matrix. Convergent validity was established by correlating the BAPS multiple-choice scores and the BAPS station scores. The resulting correlation was .80 ($p < .001$), indicating strong evidence of convergent validity. Discriminant validity was established by correlating the BAPS tests scores with the reasoning ability scores. The resulting correlation were .28 between the BAPS multiple-choice and the TOLT and .31 between the BAPS multiple-choice and the RODS. Similarly low correlation were found between the BAPS station test and the TOLT (.36) and the RODS (.38) lending support for discriminant validity. The results indicated strong support for the convergent and discriminant validity of the BAPS instruments. Considerable evidence of the construct validity of the BAPS tests can be inferred from this study. Implications of these results are discussed in regards to the current trend towards performance-based, authentic assessment in science.

POSITIVE AND NEGATIVE MULTIPLE CHOICE ITEMS
HOW DIFFERENT ARE THEY?

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The usual form of multiple choice item in most countries is a stem followed by 4 or 5 options one of which is representing the best or correct answer. The task of the student is to identify the best answer. In the biology matriculation examinations in Victoria, Australia, items have been used which consist of correct options with only one incorrect option which should be identified by the students. We shall designate the commonly used format as positive (P) and the one used in Australia as negative (N). The purpose of this paper is to compare various aspects of performance in the two test formats. In the study reported here the performance of Israeli 12th grade students on multiple choice tests consisting of positive (P) and negative (N) items was compared. Further comparisons were made between multiple choice and justification scores, performance of males and females, and performance of high and low achieving biology students. On the average the scores on P items were substantially higher than on N items. This result was explained in terms of reasoning patterns developed in the cognitive structure of students as a result of long experience with P items. There were practically no gender differences. Justifications' scores were substantially lower that multiple choice scores. Substantive differences were found between the kinds of justifications provided to the P and N items. P items proved to be more effective as a tool for identifying misconceptions.

WHAT DOES DISCOURSE MEAN IN A SCIENCE CLASSROOM?

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This study is an interpretive investigation of the language used in the teaching and learning of science at the middle school level. Classroom observations, video-taped recordings, interviews with the teacher, student teacher, and students, examination of student-produced materials, and collaborative review and reflection sessions provided the researchers with data on which assertions were built. In order to avoid entering the selected classroom with preconceived notions of what would or should be observed, the researchers purposely postponed making any assertions about language use in the science classroom until after the initial visit had been made and the video-taped recording of the class had been seen three times--by the investigators collaboratively, by each individually, then collaboratively again. The routine of recorded observation of classes, conversations with teachers and their students, and the researchers' collaborative and independent reflections provided the researchers with a means for making sense of what was being observed. It also offered insights that proved valuable for subsequent observation visits. The researchers' findings raise questions about traditional instruction and learning that focus on the language used in middle level science classes. The experienced teacher who was observed was especially effective in orchestrating carefully planned lesson activities and sequential experiences. However, close study of the actual classroom discourse suggests the following: (1) The science teacher uses science-specific and non science-specific vocabulary to present lesson content. One troubling effect is that students have difficulty differentiating between the operations of scientific principles and magical forces. They learn for example, that storms "appear" and "disappear" in the ocean, as if under the influence of a wizard. (2) Students confirm data provided by their teacher rather than construct meanings for themselves. Questions they ask provide strong evidence that they are interested in getting "the" answer rather than developing "an" answer. (3) Students learn then practice the teacher's science vocabulary and participate in small group activities in order to convince the teacher of their understanding of scientific principles. Focused observation of small group and individual activities reveals that students actually learn to use words and activities to disguise their lack of deeper understanding. Students in middle school science classes are adept at "playing school". Students in the classes observed during this study seem to have learned science vocabulary well enough to feign an understanding of scientific principles. While there was much activity during well-organized group-work sessions, careful attention to the classroom discourse reveals that lessons which are ostensibly about science are frequently devoid of concern for the learning of science.

STUDYING THE PHYSICS TEACHERS' DISCOURSE DURING LABORATORY WORK

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It is a widely accepted view that the laboratory work is an integral and indispensable medium through which subject matter is manifested and organized for students' understanding of scientific laws and principles. How subject matter is enacted and made concrete through the teacher interaction with students and curriculum materials in a research issue that needs to be seriously considered. In this context, we need to be seriously considered. In this context, we need to explore the role of the lab teaching and it implications for subject matter logical sequencing in school science teaching. Contemporary research on the issue of lab teaching has focused primarily on aspects related to the social dimension of laboratory teaching at the expense of questions dealing with subject matter organization. The main purpose of this paper is to describe how the physics laboratory is used as a medium of instruction to enact subject matter. The study basically addresses the following questions: a) What is the nature of the coherence of subject matter during laboratory activities?; and b) How this subject matter is tied up to other pieces of knowledge considered to be shared by classroom participants? The data reported is based on an ethonographic research study conducted with three experienced high school physics teachers in the mid-west (USA). The methodology involved: participant observation, video and audio taping, interviews, and document gathering. The interpretive framework is built up on constructs derived from knowledge of microethonography as applied to subject matter organization and knowledge of classroom discourse analysis. The interpretation of subject matter construction in the physics laboratory allows on to assert that: The content of physics laboratory tasks becomes problematic to both teachers and students when the teacher fails to anticipate experiences by successfully relying on previously shared pieces of school knowledge. The argument presented in this case is drawn from the "Experiment on Newton's Second Law" as it was conducted by the three participant teachers. In the specific case of this study, we describe how topics such as: velocity, acceleration, force of friction, mass, weight, inertia, and Newton's Second Law, were used throughout that school experiment. The empirical study of physics classroom discourse during lab work, in the context of whole themes or topics of the curriculum, has substantial implications for staff development and student learning. The detailed descriptions, of how experienced teachers organized this work through real time, can be used as tools for retrospective reflection on subject matter teaching and learning in high school science. Students themselves, who often are the key actors in most lab activities, can play an important role in issues related to the interpretation of their own actions and understanding as they engaged in laboratory work.

THAT'S KINDA INTERESTING, BUT IT'S NOT REALLY CHEMISTRY: CLASSROOM DISCOURSE AND THE DOMAIN OF SCIENCE

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Through classroom talk, science teachers and students jointly construct their subject matter, in both its substantive and syntactical dimensions. This paper diagrams the verbal negotiations of "science" in a single chemistry lesson. Discourse analysis reveals a struggle by a teacher and his students to reshape unfamiliar content into familiar forms. The teacher is a deliberately-misassigned university professor, studying his own language and cognitions while teaching unfamiliar content. His spoken instructions encourage students to explore the limitations of the ideal gas laws, and reveal an agenda of promoting critical discourse among students and stressing the limitations of abstract knowledge in solving real-world problems. The students, college-bound sophomores, at first seem puzzled by the teacher's agenda, then actively resist it, and eventually but reluctantly tackle problems that demand argumentation and resist precise mathematical solution. The lesson is analyzed from a sociolinguistic perspective, which acknowledges the ways in which words both reflect and reinforce differences in status, authority and knowledge in the classroom. We argue that one effect of teachers knowledge may have to insulate narrowly-defined subject matters from critical scrutiny, an undesirable outcome if the syntax of science is part of the intended curriculum. The findings of this analysis are contextualized within a three-year study of teacher knowledge and science teaching.

TELECOMMUNICATION IN THE SHARENET PROJECT

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Production of science curriculum material involves activities ranging from the generation of ideas and research to the dissemination of products. When the science units are associated with technical delivery systems, new opportunities for research are presented. Because diffusion of technological innovation involves interactions among products and their encompassing social systems, the development and use of materials may provide more understanding of the adaptation process of such innovations. Representatives from business and industry, public schools, and higher education comprise the ShareNet Partnership which provides a broad range of resources to achieve the diffusion of educational innovation. The ShareNet project joins three agencies, the University of Kansas, the ShareNet Association, and a group of the 53 school districts that compose metropolitan Kansas City in both Kansas and Missouri, and the Silicon Prairie Technology Association (SPTA) in a partnership to address the needs of science education. The purpose of this poster session is to describe and demonstrate the developmental research that preceded the award of the ShareNet Partnership grant. The University of Kansas UNITE Network was established to provide an environment for teachers and faculty to explore the ramification of developing and exchanging instructional resources. By providing a means for communication and an interface to share instruction resources, Unite provides a mechanism to connect resources to teachers in isolated settings. The second major developmental project, Project INSTEP has provided additional insight into the needs and concerns of teachers developing instructional materials for use on the UNITE Network. Project INSTEP is using workshops, network communications and school-site visitations to unite participants in the assessment of their needs. Anticipated outcomes include increased understanding of: the development of inductive instructional resources, strategies for applying computer network to enhance collaboration, and a foundation for supporting the diffusion of innovations in science education. At this time emerging needs are being documented through participatory studies, UNITE E-Mail messages, surveys, and formative evaluations of contributed resources. Information acquired during the INSTEP project will be used to further develop the UNITE Network and facilitate the ShareNet Partnership Project.

RELATIONSHIPS AMONG OPINIONS AND ATTITUDES TOWARD SCIENCE AND TEACHING PROCESS SKILLS OF LIFE SCIENCE TEACHERS

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Students' attitudes and interests in science form before they enter high school. Students' science experiences are important contributors to science achievement. If students' science experiences are directly related to their science achievement and attitudes, then their teachers are important contributors to those attitudes and achievement. Consequently, the attitudes of life science teachers toward life science teaching, along with their competence in science process skills, can be expected to influence their students' attitudes and achievements. Hueftle (1983) reported that attitudes of southeastern students toward science classes have declined in 1981. A study was undertaken to determine the attitudes of life science teachers in the southeastern part of the United States toward life science and life science teaching, beliefs about science, and science process skills. Twenty-four middle and junior high school life science teachers from the southeastern part of the United States were invited to participate in the NSF funded summer institute for life leadership teams to strengthen life science instruction in their district and state. Sixty-three percent of the sample were females. Fifty-two percent of the teachers were White, while thirty-six percent were African Americans. All teachers had advanced degrees, with three of the teachers holding Ph.Ds., fifty-seven percent of the teachers held professional certificates at the bachelor's level. Four assessments were administered to the teachers. The Survey of Opinions Toward Middle/Junior High School Science Scale (SOTSS) was used to measure attitudes toward life science and life teaching. The Scientific Attitude Inventory (Moore, 1969) was used to assess the extent to which the life science teachers assume six positive and negative scientific beliefs. The Life Science Attitude Scale, a modified version of the Revised Math Attitude, showed the attitudes of teachers toward life science courses and life science as a discipline. The Test of the Integrated Process Skill Test for Secondary Science Students was also administered to the sample of life science teachers. Significant Pearson correlation coefficients were found between the scores on the SOTSS and the SAI, scores on the SOTSS and SAI-P, and scores on the SOTSS and SAI-EMO. Therefore, teachers with a more positive attitude toward life science teaching study demonstrated that the sample had very positive attitudes toward life science and life science teaching. Although the results of the surveys indicated that these teachers possessed science process skills, the majority of teachers did not possess an understanding of the nature of science.

ENVIRONMENTAL CONTENT, BELIEF, AND AFFECTIVE CONCEPTUAL STRUCTURES AS PART OF AN OVERALL CONCEPTUAL FRAMEWORK

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Utilizing the framework of cognitive psychology, we explore and assess the content structures, belief structures and affective structures that early adolescents possess for certain environmental issues. There has been much work in science education using the cognitive psychology framework. This work has often focused on content. This study examined content, belief and affect as comprising and individual's overall conceptual framework. Since there is a lack of research which examines these three components this study attempted to explore the existence of these structures. The environmental issues of recycling, solid waste disposal, and littering were used. The following questions were explored in regard to these environmental issues: 1) What content conceptual structures do individuals possess? 2) What belief conceptual structures do individuals possess? 3) What affective conceptual structures do individuals possess? 4) What is the relationship of the three structures to each other? A clinical interview was used to determine, as completely as possible, an individual's content, belief, and affective structures about the ecological issues of recycling, solid waste disposal and littering. Eleven early adolescents (7th and 8th grade), from three junior high schools in a large urban area, participated in an hour long interview. The interviews consisted of several parts. Initially, each individual was presented with an unstructured problem about a small town whose landfill was almost filled up and asked to generate as many solutions as possible. Next, individual's were presented with two vignettes. The individual was asked to react to each story separately and then asked to compare and contrast the two. Both stories were problematic although a ready-made problem was never presented. In one story, the interviewee was in the park with a group of friends. It was implied that the group of friends littered after playing a game where cans were thrown. In the other, a manager of a fast food restaurant dumped extra garbage in a hole in an undeveloped and hidden area. Both stories were written to avoid any positive or negative affect. Each interview was audiotaped for later transcription and analysis. After all of the statements were categorized as either content, belief, affect or action, a separate concept map was constructed for each of the categories. Each subject had these four concept maps. Conceptual structures were inferred form the concept maps. The maps were first analyzed individually looking for the development of key concepts, interconnectedness of concepts, misconceptions, and common patterns. Next, the four concept maps were examined together to, again, look for interconnectedness, consistency and common patterns. We examined if one component seemed to exert a more powerful influence than the others in the overall conceptual framework. Finally, the concept maps of all eleven individuals were compared to look for common patterns.

STUDENTS' VERSUS THEIR TEACHERS' BELIEFS AND POSITIONS ON SCIENCE/TECHNOLOGY/SOCIETY (S/T/S) - ORIENTED ISSUES

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The beliefs and positions of grade 11 students who were enrolled in an S/T/S/ course (S/T/S students) and those who were not (non S/T/S students) as well as their respective S/T/S and non-S/T/S teachers were assessed on a provincial scale in British Columbia. The S/T/S beliefs and positions profiles (SBPP) of these target populations have been established and that of the S/T/S students compared with that of their S/T/S teachers and with non-S/T/S grade 11 students. Similarly the SBPPs of non-S/T/S students and their teachers were compared. Significant differences between the SBPPs of S/T/S students and teachers, non-S/T/S students and teachers and S/T/S and non-S/T/S students were found on most of the topics/issues assessed. These results and the analysis of data suggest that: (a) S/T/S education rather than S/T/S indoctrination is the norm in S/T/S courses teaching, (b) The goal of 'S/T/S-literate' students (and, apparently, teachers) has not been achieved as yet, and (c) the long-term retention capability of the established and desired SBPPs in S/T/S students is questionable.

THE "COMING DUTY OF SCIENCE TEACHING": THE STS RESPONSE TO SCHWAB

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Seventeen years ago, in a plenary address at the Annual Meeting of NARST, Joseph Schwab outlined what he saw as the "coming duty of science teaching. More specifically, he issued three challenges to members of the Association. First, engage in research at the fifth level of complexity; i.e. "enquiries which aim to disclose the full panoply of learnings which a child takes away from an experience." Second, become involved systematically and critically in determining the aims of science curricula: i.e. engage in practical enquiry which is the "determination of ends-with-means". Third, work with representatives of the other subject matters to find ways "to convey the disciplines of treatment of practical problems". Given the current ferment of science education, not to speak of the cries for reform from educational crisis managers, 1991 seems a good time for NARST to examine how it has responded to these challenges. This symposium looks at the STS response to Schwab's three challenges. Mitchener examines STS research in light of Schwab's five levels of complexity. Aikenhead and Roberts present two studies that exemplify STS efforts that further deliberations in determining science curricular aims. In addition, Roberts' study and to a much fuller extent Pereira's paper analyze STS curricula as a response to Schwab's third challenge: the role of the science education in addressing practical problems.

RECOGNITION AND REALIZATION RULES IN LEARNING SCHOOL SCIENCE - A SOCIOLOGICAL APPROACH TO PROBLEM SOLVING

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The approach to solve the underachievement in the area of problem solving has been of a fundamental psychological basis. Contrarily to such trend, the study described in this paper takes into account the sociological processes of learning and transmission at both the family and the school. The research is based on Bernstein's theory in the sociology of education and uses as the main instruments of analysis his concepts of recognition and realization rules, his concepts of classification and framing, and his concept of pedagogic code. The sample is constituted by 80 students of the 5th-6th years of schooling (11-12+ years of age) separated in three sets each of which was submitted to pedagogic practices differing in terms of power (classification) and control (framing). The classes were all socially heterogeneous and similar in terms of social class, race and gender. The data were obtained through questionnaires and interviews. The intention was to see the extent to which students have recognition and realization rules at the micro context of problem solving within the broader context of learning in the science classroom. To this end, a first instrument was applied to the whole sample to measure students competence to recognize between two types of competencies (competence A - low level of abstraction and competencies U - high level of abstraction). This was followed by interview to a sub sample of 30 children. These interviews were structured in several inter-related parts. With the data obtained two indexes were constructed: an index of recognizing the school text, i.e. recognizing between the two contexts A and U, and an index of realizing the school text, with its two dimensions selecting the text and producing it. These indexes give some indication of the recognition and realization rules students possess. The data were then analyzed in relation to social indicators, some of which were related with the family (social class - father's and mother's academic qualifications and occupations - race) and some related with the school (pedagogic practice, science achievement in U competencies). The data were also related with students coding orientation in a more general context, measured in a study related to the research reported in this paper. The results show a general relationship with social class, race, pedagogic practice and achievement. Interesting subtleties of this relationship will be a matter of discussion of the paper. The results suggest some reasons for the difficulties many students encounter in problem solving situations and give possible directions to be taken into account in science pedagogic practice.

STUDENTS' DIFFICULTIES WITH SUBSCRIPTS IN CHEMICAL FORMULAS

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A classroom based study of students' understanding of the subscripts in chemical formulas was conducted. Students completed paper and pencil tasks which involved basic chemical arithmetic. In these tasks the students had to work with information such as the mass of a substance that was present, the molar mass, the number of atoms present and the chemical formula for the substance. The study employed two different task formats, ranking tasks and multiple-choice questions, and two different kinds of substances, real and imaginary. The task formats were designed to make it possible to draw inferences about how the students worked the tasks. This permitted us to determine how the students who did the items incorrectly actually worked the tasks. Students in four classes of three different courses were tested with the tasks. One course was for science majors, one was for engineering majors and the third was for students who had never studied chemistry. In all cases the tasks were administered as extra-credit opportunities, and generous time constraints were applied. Students were tested after they had studied basic stoichoimetry and had worked related problems. The results demonstrated that students had trouble making use of the information, about the number of atoms in a molecule, that was contained in the subscript. This was shown by two things. First, the number of students answering the tasks correctly was low, there was only one item which more than half of the students managed to answer correctly. Second, the alternative procedures that the students used either ignored the subscript information, or used it incorrectly. Implications of these results for teaching chemistry will be discussed.

EFFECT OF INFORMATION FORMAT ON STUDENTS PROBLEM SOLVING STRATEGIES

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This study was designed to examine how student' strategies vary with information format in solving problems involving the mole concept. Students in four different first semester college chemistry classes were given two different ranking tasks: Atom Total and Mass of Substances. The Atom Total task required the students to rank eight containers form least to greatest based on the number of atoms present. Information given was mass, molar mass and number of atoms per molecule. The Mass of Substance task required that students rank eight containers on the basis of actual mass present. Information given was the number of atoms present, the molar mass and the number of atoms per molecule . Information concerning the number of atoms per molecule was presented in three different ways: verbal (e.g. 5 atoms per molecule, diagram, and formulas (e.g. D_5). The researchers were able to identify almost all of the strategies used by students which ranged from ranking on the basis of mass alone to correct. In each case, there was a definite increase in the percentage of students using the correct strategy in going from formula to diagram to verbal format. There was, in general, a decrease in the use of the common alternative strategy which ignored the subscript, in going from formula to diagram to verbal description of the number of atoms in the molecule. On the basis of these findings, we believe that symbols used by chemistry teachers do not easily become a part of the conceptual understanding of pupils. Teachers must explicitly show examples of the different ways chemist have of identifying the number of kinds of atoms in a molecule.

GROUP VERSUS INDIVIDUAL PROBLEM SOLVING IN A LARGE INTRODUCTORY PHYSICS COURSE

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A survey of the 24 departments at the University of Minnesota that require their majors to take a two-quarter, algebra based physics course indicated that one important goal of the course is for students to develop general quantitative problem solving skills that they can apply to new situations. To meet this goal, we introduced a problem solving strategy that required students to make a systematic series of translations of the problem into different modes of representing the problem, each in more physical and mathematical detail. To get students in the large lecture course to practice using this strategy in a way that fosters success, we implemented cooperative groups. However, this solution reflects the work of the best problem solver in the group. In this study, we investigated two questions: (1) Is the problem solving performance of groups significantly better than the performance of the best individuals from these groups on matched individual problems; and (2) If so, which components of problem solving are performed better by groups? In 1989 we developed and tested rating scales to measure three components of problem solving from written solutions: describing the problem in physics terms, generating a plan, and executing the plan. Since the strategy emphasized translations from one mode of representation to another, we developed two rating subscales for each of these three components, a translation scale as well as a quality scale. These six subscales, which have an interrater reliability of 0.85, were combined to form one ordinal score of competent problem solving. The scales were used to analyze the problem solutions from one section of the 1990 course. Of the 91 students who enrolled in both quarters, 60% were freshman and sophomores; 43% were females. The students practiced using the strategy to solve problems in assigned heterogeneous (by ability) cooperative groups of three students in their weekly discussion sessions. The composition of the groups changed two or three times a quarter. Each test consisted of one group problem solved in the discussion section, a short qualitative question, and two problems solved individually in the lecture period the next day. The Wilcoxon Rank-Sum Tests comparing the performance of group on six test problems with the performance of the best problem solvers from each group on the six matched individual problems were all significant at the $p < .05$ level. We concluded that the group problem solutions are not simply the work of the best individuals on all subscales. The biggest differences occurred in the quality of physics description; groups generated physics descriptions with fewer misconceptions and serious omissions. This result supports the theory that in groups, students can share argument roles and request clarification, justification, and elaboration, so that a better resolution emerges than could be achieved by the individuals working alone.

HOW TO MAKE LEARNING OF PHOTOSYNTHESIS MORE RELEVANT

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Photosynthesis is perceived to be one of the most important subjects in biology and one of the difficult ones. Many students report on misconceptions students have about photosynthesis, even after studying the subject (Barker, 1985; Bell & Brook 1984; Cho, 1988; Eisen & Stavy 1988; Simpson & Arnold 1982; Stavy, Eisen & Yaakobi 1987; Wandersee, 1983). Researchers and teachers continue to try finding ways to teach photosynthesis so as to minimize the misconceptions (Barker, 1986; Bell, 1985; Bishop, Roth & Anderson, 1984; Roth & Anderson, 1987; Simpson & Arnold, 1986; Stavy & Eisen, 1989; Yaakobi, 1989). In this study, an attempt was made to examine whether students who study according to a science curriculum developed on the basis of research on misconceptions, would improve their understanding in comparison to students who were not exposed to this curriculum. Our approach to the teaching of photosynthesis was to build on the intuitive conceptions of children, and to organize the content and the teaching in such a way as to avoid the formation of misconceptions in the first place. The purpose of the study reported in this paper was to compare how students who learned through the two different approaches - our innovative approach and the former teaching unit - understand concepts concerning photosynthesis. We examined students' understanding in four different topics: ecosystem, chemistry, autotrophic feeding, and respiration. We assumed that if a student understands the role of each one of the topics in the photosynthesis process he/she probably has a reasonable basic understanding of photosynthesis. The results indicated that students who studied using the new approach scored significantly better than those who studied through the other approach. Analysis of the responses in the various topics showed that the main differences between the groups are in the respiration topic and in the ecosystem topic. In the chemistry topic the experimental group also scored better than the control group, and in the autotrophic feeding topic they scored about the same. We may conclude that an approach which takes misconceptions into consideration, and which is related to both content and teaching methods can be more relevant to students and can bring more understanding of problematic scientific issues like photosynthesis.

TEACHING EVOLUTION: UNDERSTANDING, CONCERNS, AND INSTRUCTIONAL APPROACHES

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The investigators sought to examine the influence of a three-week institute upon secondary biology and earth science teachers regarding their self-confidence with respect to the teaching of evolutionary principles. The institute, funded by the National Science Foundation, was designed to promote the philosophical and applied nature of science, provide enhanced content, and provide a forum for teachers to discuss common problems associated with the teaching of evolution. In concert with the instructional conduct of the institute, the following research questions were proposed: 1) To what extent can a three-week institute influence teachers': (a) understanding of the nature of science; (b) acceptance of the theory of evolution; or (c) understanding of applied evolutionary principles?: (2) Can a three-week institute reduce teachers' self-perceived anxieties regarding the teaching of evolution? and . . . (3) What concerns might teachers have regarding the potential use of a student-centered, peer discussion as an instructional strategy to teach evolution? The nineteen institute participants were required to actively engage, both formally and informally, in discussions related to both content presentations on both biological and geological themes and variety of instructional activities designed, taught, and modelled as teaching methods by the principal investigators. The scope of these activities ranged from field trips to both ecological and fossil sites, to traditional lectures, question/answer, small group issues discussions, and other creative inquiry-based methods of instruction. The final week was used to provide participants an opportunity to research and design (days 11 and 12) an activity for eventual presentation to fellow participants (days 13-15). At the conclusion of the institute, participants showed significant increases in their acceptance of the theory of evolution ($Z = 2.93$; $p < 0.01$), content understanding of evolution ($Z = 2.74$; $p < 0.01$), and an applied understanding of the nature of science ($Z = 2.84$; $p > 0.01$). In addition, participants experienced a significant reduction in their anxiety ($Z = 3.51$; $p > 0.01$) regarding the teaching of evolution in the secondary science classroom. Finally, a qualitative examination of the participants' Stages of Concerns (Sac) composite profiles for normative "pretest" and "posttest" percentile data, indicated a shift away from the three lower (Awareness - Stage O, Informational - Stage 1; and Personal - Stage 2) and toward the three higher (Consequence - Stage 4; Collaboration - Stage 5; and Refocusing - Stage 6) Stages of Concern. In addition, the relative shifts occur in a direction that favors a moderate to strong consideration for the use of a peer discussion instructional format for the teaching of evolution.

ELEMENTARY TEXTBOOKS VERSUS THE CHILD: CONFLICTING PERCEPTIONS IN BIOLOGY

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An ethnographic study was conducted with the goal of comparing the botanical knowledge of nine sixth grade students with the botanical concepts found in the elementary textbook series, Science, by Silver Burdett, 1985 (Tull, 1990). The researcher wanted to determine the extent to which the child's conceptual framework resembles that of the scientist, and the extent to which the textbook reflects the knowledge base and abilities of the child. The researcher examined each child's language, meanings, classifications, and interpretations of botanical phenomena. The children participated in a series of six interviews and tasks. They identified plants from slides and in two outdoor field trips. They sorted photographs of plants into categories. They developed concept maps of various botanical concepts. They discussed the functions of leaves and flowers and other plant parts, as well as the environmental needs of plants, human uses for plants, the differences between plants and animals, and the differences between living and non-living. The children's names for plants and plant classification schemes were examined using domain analysis, componential analysis, and taxonomic analysis (Spradley, 1979). An examination was made of the botanical concepts in the first through sixth grade textbooks. All statements related to botany were classified as either concrete or abstract. All names for plants were classified as either being familiar or unfamiliar to children in central Texas. Concept maps were made from the botanical statements in the text. The concept maps were used to examine the development of each concept. The data revealed that the children had a large body of knowledge about plants. The child's botanical language, meanings, classification scheme, and interpretations of botanical phenomena were more closely aligned with that of the adult layman than with that of the scientist. The children's botanical language and meanings appeared to be learned from the lay culture rather than from the textbook. The textbooks relied heavily on scientific vocabulary and abstract botanical concepts. The areas of strengths for the children (e.g., recognition of plants at the generic and family level) were areas neglected by the textbooks. The textbook neglected to guide the child into an early understanding of the concrete botanical phenomena (e.g., the names for the parts of a flower) necessary to the understanding of related abstract phenomena (e.g., the function of those parts in reproduction). The textbooks did not succeed in bridging the gap between the knowledge and abilities of the child and those of the scientist.

SCIENCE TEACHERS' PERCEPTIONS ABOUT WRITING IN SCIENCE: A REPORT ON PHASE II -- INTERVIEWS

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In Phase I science teachers' perspectives or world views about writing in science were explored using a questionnaire survey. Information was collected concerning their views about their own writing, teaching and evaluating writing, their students' writing, the purposes of writing, the contribution of writing to learning science, and the kinds of writing science teachers do. Phase II of this study was designed to continue and expand the exploration of these questions and issues through individual interviews. Five science teachers participated in the four interviews over a five month period. Research questions were developed based on the belief that science teachers' views about their own writing and about teaching and evaluating writing in science would be the primary factors that influenced their perspectives about writing in science. However, during the course of the interviews and data analysis, other factors emerged as more explanatory. Twenty three science teachers who responded to the questionnaire volunteered to participate in Phase II of the study. Using cluster analysis to identify relevant subgroups, two issues were found to best describe the differences between the subgroups -- what about writing should be graded and the emphasis placed on writing in science. Based on their differences in perspective about these issues, five science teachers were asked to participate in the interviews. A series of four interviews and three days of classroom observation were conducted from February to June, 1989. Teachers were contacted by telephone to arrange the initial interview. The interview procedures were based on Spradely's notion of an ethnographic interview, in that the researchers assumed an ignorance of teaching science in Georgia and of other teachers ideas about writing in science. Spradely argues that placing the participant in the position of informer, the one who is more knowledgeable about the topic of conversation, makes the interviewee more comfortable and more likely to share information that under different circumstances they might assume the interviewer already knew. Each interview had a predetermined agenda but was open to redirection depending on the comments and interests of the teacher. The interview data were analyzed and interpreted using a coding and categorization system similar to Glazer and Strauss's (Strauss, 1986) methods of constant comparison. Interview tapes were transcribed; transcriptions were reviewed for accuracy and edited by the researcher when necessary. Science teachers' belief systems about writing in science are complex. Each of the science teachers had a set of core beliefs about writing's contribution to learning. Common among these beliefs was that writing allowed students to get across what they knew, to communicate. Even so, all five teachers agreed that teaching writing was not their responsibility. Throughout their talk, there was evidence that their own writing processes and experiences with writing influenced the ways they utilized writing in their science classes.

RESEARCH WRITING IN SCIENCE TEACHING: NSTA AND NARST WORKING TOGETHER

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Research on reading and writing has major implications for future research on improving science teaching. This critical analysis and theoretical paper views these two intellectual skills as interactive and symbiotic factors useful in facilitating critical thinking and high order thinking in science classrooms. In addition, recommendations are made for research in science teaching centering on comprehending and composing strategies and based on experimental designs using modern-day processes and product measures. This is the research-focused paper produced by the National Science Teachers Association (NSTA) Task Force on Science Education, Reading and Writing. Reading and writing are an integrated series of thought processes whereby authors and audiences with particular prior knowledge, strategies and dispositions interact with one another through science texts forming verbal meanings in their minds. NSTA in its preamble to its central landmark position paper, "Science teachers speak out: The NSTA lead paper on science and technology education for the 21st century," identified the central Association goal - helping science teachers produce scientifically literate people and develop informed thinking citizens, and productive professionals such as ". . . qualified scientists, engineers, [and] teachers. . .". But, according to research studies, this central goal requires schools to develop reading and writing skills to develop higher order and critical thinking often in ways contrary to common practices, according to research studies. First, students need to learn how to read and write in the context of the science classroom and not restricted to the context of language arts classes, as is the case in most of today's schools. Second, research supports the principle that reading and writing should begin in kindergarten and at the same time, and in an interactive and symbiotic fashion, rather than teaching reading before writing and separate from writing. This finding means that reading and writing in science classes in earlier grades is judicious, but inconsistent with current practice in most science classrooms, as is suggested by research in language arts. Teaching these skills does not have to destroy the attitudes and curiosity of youngsters. Third, much of what is learned during reading and writing can facilitate the development of both skills because of their similarities which need to be made explicit to students of all ages. Yet reading and writing have important differences -especially important to teachers and people involved in curriculum development work, as suggested by Tierney and Shanahan. For example, correlational studies between measures of reading and writing on individuals seldom attain coefficients above 0.60 and typically between 0.25 and 0.40, suggesting a surprising amount of intellectual independence between reading and writing. In this same vein, very good readers are not always very good writers, yet many teachers apparently assume that writing activities in classes like science are not relatively important because reading practice directly facilitates writing skills, providing students have ample time to develop their reading skills. This kind of thinking may make pedagogical common sense to some but in reality represents educational folklore.

INVESTIGATING SCIENCE CONCEPTS THROUGH WRITING ACTIVITIES

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This paper will examine the role of writing as a tool to support knowledge development and conceptual change in science. The role that writing played in fifth graders' developing understanding of important science concepts will be traced across a school year. The context of the study was unusual in that the researcher assumed the teacher-researcher role, teaching science each day during 1988-89 to a class of 29 fifth-grade students. An overarching goal of the study was to explore what is possible in terms of student learning when a conceptual change model of teaching guides instruction across an entire school year. Analysis of students learning revealed significant conceptual development in students of all ability levels. Writing activities were identified as critical supports in that knowledge growth. This paper analyzes the nature of students' use of writing across the year to extend and reformulate their understanding of science concepts. Key features of writing assignments that foster idea development are described. These include: engagement in thinking processes and problem solving, students' thinking and idea development as primary, connections between personal knowledge and subject matter concepts, connections and development of concepts across time, usefulness of subject matter concepts, and appropriate written form and audience. The instructional support needed to implement writing activities effectively is described, using examples from this fifth grade classroom.

RANDOMNESS, REPLICATION AND RESEARCH DESIGN IN FIVE YEARS OF THE JOURNAL OF RESEARCH IN SCIENCE TEACHING

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We examined research studies reported in the most recent five-year period in the Journal of Research in Science Teaching (JRST) to determine the extent to which science education researchers use commonly recommended research methods and procedures. We analyzed all the experimental studies (130) reported in volumes 22, 24 and 26 of JRST, but we did not include articles in the following categories: literature reviews or meta analyses, instrument development or validation, philosophical inquiries or position papers, historical studies. The majority of the studies we reviewed employed either true-experimental or quasi-experimental designs, but increases in the proportion of survey and ethnographic studies were observed over the five-year period. We addressed five questions: (1) Do science education researchers typically select their samples randomly from defined and/or described accessible populations? (2) Do science education researchers define their target populations and describe their samples? (3) Is replication a frequently used research strategy in science education? (4) Do science education researchers restrict their conclusions to the limitations in their sampling techniques or in regard to possible differences between their accessible and target population? (5) How do the results for JRST compare with the findings for the American Educational Research Journals (AERJ) and Theory and Research in Social Education (TRSE). The answers to these questions were essentially the same as the answers arrived at when general educational research and social studies researchers did not typically use random selection in choosing their subjects, and most neither provided the reader a definition of their target population, nor an adequate description of the accessible population. Further, over one-third of the studies examined contained no demographic information on the sample used. Together, these results indicate that appropriate generalizations beyond the confines of the reported studies may be impossible for most JRST studies. We also found that replication, a research strategy which could be employed to offset deficiencies in generalizability, was not often used in these studies. In addition, the results of this study indicate that many researchers do not properly restrict their reported conclusions to the limits imposed by the accessible populations and samples used. These findings raise important questions about the nature of the science education research enterprise and the worthwhileness of the results produced (research articles).

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SPECULATIVE PHILOSOPHICAL ANALYSIS OF PRIORITIES FOR RESEARCH IN SCIENCE EDUCATION

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Philosophical research is common, but it is atypical of the quasi-empirical methods that characterize most educational investigations. Consequently, its unique qualities are unfamiliar to many science educators; and it is sometimes confused with other forms of inquiry such as historical, naturalistic, futuristic, or correlational research. The purpose of this study was to review the nature and purposes of philosophical analysis and make recommendations about the applicability of that research methodology to the field of science education. Philosophical research functions to examine purposes, justify fundamental assumptions and concepts, and illuminate options that are compatible with the aims and ideals of an institution, agency or group. This methodology is unique in that it does not function within an enterprise. Rather, it functions to think about an enterprise that may face a need for change. As a result, philosophical research does not require the disruption of an enterprise to seek alternatives and justify options. Ideally, it provides an efficient means for putting complex problems in the proper perspective to determine if change is appropriate prior to the commitment of resources and time to a given course of reform. It was concluded that, given the current pressure for reform, those features render philosophical analysis essential for initial research into broad educational issues such as the basic purposes of science education, the Science-Technology-Society relationship, the ideals of general scientific literacy and lifelong science learning. Topics considered in the study over a five-year period included the curricular implications of the origins of science education, the role of the history of science in teacher education, and the instructional implications of the problem of common scientific misconceptions. Philosophical examination of those issue areas culminated in recommendations for priorities in research that the science education community should consider as it attempts to respond to the pressure of reform.

TWENTY-FIVE YEARS IN JRST: RESEARCH TOPICS, METHODS AND ISSUES

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This paper summarizes the past twenty five years of research published in Journal of Research in Science Teaching with attention to topics of study, research design and other salient characteristics. Issues of the Journal for the years 1965-1989 were randomly selected, taking into account the number of issues per year which rose from 4 in 1965 to 6 in 1976 and 9 in 1982. For each issue selected, all articles originating in the United States and Canada were classified by topic, subjects, methods used to gather data, research design and any special features. Research originating outside North America was noted but was not included in the calculations. The major lines of inquiry found in the analysis were curriculum comparison studies, effects of instructional strategies, Piagetian studies, concept development studies and case studies of teachers, pupils and classrooms. Research designs were classified as correlational, experimental or quasi-experimental. Correlational designs were found to have been used in almost twice as many studies as experimental and quasi-experimental designs combined. Issues raised by the review and current research trends are identified and discussed. The question is raised as to why this considerable body of work has had so little impact on curriculum design, classroom practice and assessment of achievement in science education. It is suggested that science education is still a field without a methodology of its own, asking the questions of an applied field but using the language of basic research.

A CASE STUDY OF PRIMARY SCIENCE TEACHING IN MALAYSIA

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This is a report of a case study of primary (elementary) science teaching in Malaysia. This research was designed to gain an understanding of the processes of science teaching in a standard 6 (grade 6) classroom after about two decades of an "inquiry-based" curriculum being implemented. This research was done using an ethnographic method; that is, the techniques employed by anthropologists were being used to discover the "mechanics" of science teaching in a classroom. Data were collected using classroom observations, interviews with the teachers, and analysis of pertinent documents. Field notes were written, interviews were tape-recorded, and relevant documents were collected. The process of data collection lasted two months. The primary school chosen as the research site was located at the outskirts of a small town. It was an exemplary primary school in the district. Students in this school were mostly from the lower and middle class in the SES of Malaysia. The teacher involved in this study was a twenty-four year old married woman. She had been teaching for more than five years and was an exemplary teacher in that school. Findings from this study suggest that the primary science curriculum reforms began about two decades ago in Malaysia were only minimal in impact. A new syllabus and new textbooks were used but the methods of teaching science apparently did not change as much as intended. Students were observed conducting an experiment, watching relevant programs on Educational Television, and using an encyclopedia as reference during this study.

DESCRIPTIVE CHARACTERISTICS OF SCIENCE/MATHEMATICS EDUCATORS AND FACTORS THAT DISCRIMINATE THEM FROM SCIENTISTS/MATHEMATICIANS AND OTHER EDUCATORS USING DATA FROM THE THIRD FOLLOW-UP OF HIGH SCHOOL AND BEYOND

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The High School and Beyond senior data set (N = 11,995), collected by the US Department of Education's Center for Statistics, was used to construct a Science/Mathematics educators group (N = 34). This group was described in comparison to Scientists/Mathematicians (N = 281) and Other Educators (N = 237). Bivariate and multivariate statistical analyses indicate that the Science/Mathematics educators group can be characterized as a small percentage of four-year college graduates (1.2% of this sample; $N_{\text{four-year college}} = 2917$) made up of people with a significantly high percentage of fathers who are school teachers. Their background high school science and mathematics coursework is strong (especially for males), but not as strong as that of Scientists/Mathematicians. Their plans were strongly influenced by adults during high school and after high school, and they had a high school level of achievement that was not significantly different from education majors in general. They were also less likely to be in the academic track than either Scientists/Mathematicians or Other educators. The Science/Mathematicians educators group is best discriminated by the variables: having a father who is a school teacher, strong parental influence on high school plans, a high percentage of teachers/counselors recommending college attendance, low high school achievement, low percentage in the academic track and gender (female).

SCIENCE TEACHERS: A COMPARATIVE PERSPECTIVE

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Drawing on data collected by questionnaire from teachers during the Second International Science Study (SISS) organized by the International Association for the Evaluation of Educational Achievement (IEA) between 1983 and 1986, the education, job characteristics, professional activities, and instructional methods of science teachers in Hungary, Israel, Japan, Korea, Singapore, and the U.S.A. are described quantitatively. Their statements of the relative importance of various factors in determining what they taught on day-to-day basis are also considered. Teachers described in this study taught students populations I (10-11 year olds) or II (14-15 year olds). As part of the IEA SISS the teachers of students tested were given a Teacher Questionnaire, and responses of teachers from Hungary, Israel, Japan, Korea, Singapore, and the U.S.A. to that questionnaire are considered in this study. The teachers sample is not a random sample, since teachers responding were those who taught science to the sample of pupils whose science achievements were surveyed by SISS. The number of teachers given the questionnaire varies from country, but sample sizes are substantial, with a total of 1,653 teachers from the six countries at Population I level [Hungary (N=97); Israel (N=96); Japan (N=545); Korea (N=560); Singapore (N=232); U.S.A. (N=123)]; and a total of 1,696 teachers at Population II level [Hungary (N=354); Israel (N=59); Japan (N=314); Korea (N=625); Singapore (N=225); U.S.A. (N-119)]. The responses of teachers of Population I are first described. This is followed by consideration of the responses of Population II teachers, when contrasts are drawn between responses of teachers of those two populations. Limitations of the work are noted, and suggestions made for further investigations. Few studies of teachers characteristics, education, and instructional methods use an international perspective since the difficulty and expense involved in collecting adequate data may make such an enterprise both costly and impractical. The use of international data collected by IEA studies provides a rich source of information.

TRAINING STUDENT-TEACHERS IN THE USE OF COMPUTERS IN SCIENCE CLASSROOMS

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In this study a program on using computers in science classrooms was developed and implemented in a pre-service training course and student-teachers' attitudes were investigated. The participants in this study were 31 students (8 males and 23 females). The students studied toward a BSc degree in Biology and a Certificate of Teaching for Junior and Senior High School in a four year program. During the four years they simultaneously studied biological science and educational courses. The course "Using Computers in Science Lessons" was offered in their third year of studies. The duration of the course was 15 weeks, two hours per week, thus a total of 30 hours of training. The program included a sequence of activities in which student-teachers became acquainted with the use of relevant software in their subject matter and critically discussed how to integrate the computer assisted learning (CAL) into an existing curriculum in their science classrooms. Data obtained in a post-test attitudes questionnaire was compared with the pre-test data and analyzed with a t-test. The results showed that students' attitudes became more positive in four factors: teaching strategies, understanding science, classroom learning, environment and students' self-esteem. Development and implementation issues of CAL in a pre-service training course will be elaborated.

LEARNING IN THE MIDDLE SCHOOL EARTH SCIENCE CLASSROOM: STUDENTS USE INTELLIGENT LASERDISCS TO CONCEPTUALLY INTEGRATE NEW KNOWLEDGE

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National statistics indicate students' overall interest in science declines dramatically in the middle grades. Pascarella et al. (1981) found that "the extent to which teachers, rather than students, controlled the learning environments was negatively associated with continuing motivation." In related studies Sherwood et al. (1987) and Bransford et al (1988) used videodisc technology to create shared "macrocontexts" between teachers and students to explore a variety of problem solving strategies. These studies build on the assumption that "both children and adults act to solve problems and accomplish purposes which are functional and meaningful within the context", and that these contexts should be semantically rich (Rose et al. 1990). It is this richness in vocabulary, phrasing and visual information of contextual learning which can be uniquely created and recorded by a hypermedia/laserdisc authoring environment. To be "meaningful" these contextual learning experiences must be related to prior knowledge and integrated into the student's knowledge framework. Preparing a concept map requires organizing knowledge and enables students to relate their prior knowledge to new events and objects. Gowin and Novak (1984) proposed concept mapping as a tool for learning and for research. Concept maps are schematic representations of an individuals structure of knowledge and have been used by students to show their extent of relevant prior knowledge, knowledge gains, and change in knowledge structure. Similar to concept maps the software product HyperCard "enables users to idiosyncharatically organize information in a manner like that of the user's own thinking" (Hypermedia, 1988). Combining hypermedia with the visual database available on optic discs in educational settings provides a unique opportunity to research how students construct new knowledge. This media enables researchers to record students' decision making as they select and deselect information to integrate into their conceptual framework while learning. This study was designed to describe how middle school students select, link and determine relationships between textual and visual information. Sixteen authoring groups (3 students/group) were formed from two eighth grade earth science classes and each produced laser videodisc lessons about "weather" for their classmates. Students used hypermedia on Macintosh computers with videodisc players and color monitors for authoring these lessons. Laser videodisc authoring allows students to link visual and textual information, describe those links, and facilitates the development of cross-link wherever students recognize a relationship between video and text information. Results indicate that use of laser videodisc in the middle school classroom extends students' possible learning experiences, motivates students to stay on task, and can be effectively used by students for meaningful learning.

THE DEVELOPMENT AND PARTIAL VALIDATION OF THE MICROCOMPUTER UTILIZATION IN TEACHING EFFICACY

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Considering that reports call for the need for improved use of microcomputers in our schools, one might think that computers are widely used in schools, particularly in science instruction. This is not the case. When teachers were asked how much they use computers in science classes, they indicated that typically science students spent fewer than 15 minutes per week working with computers. Researchers reported that 85 percent of the students in one study never used a computer in science class. The Microcomputer Utilization Teacher Efficacy Beliefs Instrument (MUTEBI) was developed to measure the beliefs of inservice teachers. Based upon Bandura's social learning theory, the two sub-scales of the Microcomputer Utilization in Teaching Beliefs Instrument (MUTEBI) measure constructs of self-efficacy and outcome expectancy with regard to utilizing microcomputers in teaching and learning (science). Item and factor analyses revealed results consistent with previous research (Riggs, 1988; and Enoch and Riggs, 1990). The scales are homogeneous and distinct. The MUTEBI should be helpful in future investigations involving the use of microcomputers in instruction. Behavior is based upon beliefs. If science education is to be improved via the use of microcomputers, teachers must be willing to devote more time and energy to their use. Increased self-efficacy and outcome expectancy beliefs are predicted antecedents to this behavior change.

REFLECTIVE TEACHING AND CONCEPTUAL CHANGE IN AN INTERDISCIPLINARY METHODS COURSE

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This study examined the extent that writing-to-learn and reflective teaching within an interdisciplinary elementary methods course gave undergraduates the opportunity to change their perspective from being a student to being a teacher. The conceptual framework for the study was drawn from the research on reflective teaching, conceptual change, and writing-to-learn. Thirty-one preservice elementary education majors enrolled in a one semester interdisciplinary methods course involving science, reading and language arts served as the study population. A number of on and off campus whole class experiences were devised to provide a "cognitive apprenticeship" through a variety of opportunities to observe and experience life as a teacher and exposure to children. The course was team taught by two faculty, two days per week for six hours per day. Data for this study was collected mainly through students' writing of various forms and purposes throughout the semester. In addition, videotapes were made of many of the science classes. The researchers kept thorough field notes of each day's class proceedings. Additional data came from individual and small group spontaneous discussions outside of class time. Data analysis began by reading and rereading complete sets of assigned papers in chronological order to absorb the "story" of individual students juxtaposed against the patterns discerned from all of the student papers. Significant patterns that emerged from the data include the following: (1) The structure of the course itself, as an interdisciplinary workshop that first asked students to consider themselves as scientists, readers and writers, forced all students to confront their self-concepts in each discipline. (2) The structure of the course with its emphasis on written reflection through many different genres of writing served as a catalyst and allowed most students to discover just what, at that point in their career, troubled them most about teaching science, reading, and language arts. (3) The structure also forced them to see themselves evolving from "just being college students" to beginning to think as rational/intuitive decision-making teachers. Students honestly began to "see themselves as teachers of science, reading, and language arts." (4) The findings of this study seem to indicate that students have a richer background than that of a "novice". One of the critical findings of this study is that, while no students entered the class "table rasa", no two students grew in their ability to reflect on teaching in the same way. There were three broad categories of students within this continuum range: traditionally aged students who had very unspecified concerns, nontraditional students who also had very unspecified concerns, and nontraditional students who came to class with broad but tentative teaching concerns.

CHANGES IN THINKING AS A CHEMISTRY STUDENT BECOMES A CHEMISTRY TEACHER

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This is the report of a study which examines the first four years of a beginning chemistry teacher's career. The authors explore the difficulties that are faced by the new teacher as she attempted to transform her formal knowledge of chemistry and pedagogy into the practical application of a high school chemistry teacher. The report includes the teacher's difficulties in gaining control in the classroom; in organizing, planning and conducting lessons; and, in dealing with the constraints that were placed on her by school officials, peers and the expectancies of students and parents. The report will examine curricular expectancies in high school chemistry including the dominance of the text and tests, the mixed signals from peers and administrators which beginning teachers must clarify and the sources of support that are available to assist new teachers in the early stages of their professional development. The study examines growth in a new teacher's knowledge of content, pedagogy and "pedagogical content" during a four year period, as seen through her own eyes, those of her mentor and those of a university researcher.

A QUALITATIVE STUDY OF PRESERVICE ELEMENTARY TEACHERS' UNDERSTANDING OF PHYSICS CONCEPTS

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The constructivist approach to education holds that "knowledge is constructed in the mind of the learner" (Bodner, 1986, p. 873). As learners build their conceptual patterns, adjustments and restructuring must take place if learners are to accept a scientist's interpretation of a phenomena. Therefore, rather than adding new knowledge, learners construct knowledge within their own mind (Hewson & Hewson, 1988). If one holds to the constructivist's view, then teachers as learners must build their conceptual structures in which they incorporate their content knowledge and knowledge of teaching. The overall purpose of this study was to observe and document the thoughts and beliefs concerning physics concepts held by preservice elementary education majors enrolled in an introductory physics course and an elementary science methods course. The researcher was primarily concerned with the questions: What are preservice elementary teachers' understanding of physics concepts having completed a science education concepts course?, and, Are the understanding of physics concepts maintained over an extended period of time? As the researcher was interested in understanding preservice elementary teachers' understandings of physics concepts, the primary data source for the research was obtained through the use of clinical interviews. The researcher interviewed participants in a university level introductory physics course and an elementary science methods course. Each interview was audio and videotaped. The tapes were then transcribed and analyzed through analytic induction. In addition to these data, additional data were obtained through participant observation and artifacts obtained during the course instruction (e.g., homework, examinations, and quizzes). Through the analysis, the researcher has scanned the data for categories of phenomena and for relationships among these categories. In this manner the theory produced is grounded in that the data that are generated during the study.

A QUALITATIVE STUDY OF THE BELIEFS AND PROFESSIONAL BACKGROUNDS OF SECONDARY LEVEL SCIENCE TEACHERS IN A PUBLIC SCHOOL AND A PROTESTANT CHRISTIAN SCHOOL

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Secondary science teachers in a public school and a Christian school were studied in terms of their educational background, beliefs and classroom practices. This study was qualitative in nature, and incorporated classroom observations and taped interviews which were designed to reveal what each teacher believed about such matters as the nature of science and knowledge, the nature and purpose of education in general and science education in particular, and basic beliefs regarding God and purpose in life. Information on the educational background of each teacher was also collected, and compared with the other two components of the study. Information from this study was used to compare these five male teachers' stated beliefs with their educational backgrounds and their classroom practices. Each teacher revealed that his world view leads him to concerns for the world in general, and for his students in particular. The major difference between the two sets of teachers and the way each set teaches lies in their sense of responsibility of what they should teach their students, and this centered on their concept of God, and the question of origins. The two Christian school teachers believe in a very real and personal God, to whom they have a definite responsibility to be obedient. For the classroom, this obedience means that they must teach a literal, six-day creation, and that evolution is an incorrect theory of science. The public school teachers do not believe they should try to guide their students toward any set religious world view. Instead, they accept evolution as a valid scientific theory, and in general, present students with a more or less non-theistic interpretation of the natural world. Analysis of relationships between world view and professional background suggests that the context in which the teachers themselves were taught science affected their beliefs regarding origins. The Christian school teachers were taught in college that the biblical concept of a six-day creation is the correct answer to the question of origins, whereas the public school teachers were taught standard principles of organic evolution. As a result, the Christian school teachers teach the creationist view of origins as the only possible answer, whereas the public school teachers present evolution independent of any discussion of God. One of the teachers had almost no science coursework at all while in college. This teacher seldom incorporated any hands-on activities into his lessons. Instead, he relied almost exclusively on lecture. The teacher who made most use of hands-on activities has a background in outdoor experiential education. Each stated that his method was the proper way to teach science. For these two teachers at least, the evidence suggests that their backgrounds does influence their manner of teaching.

A STUDY OF CHANGES IN MIDDLE SCHOOL TEACHERS' UNDERSTANDING OF SELECTED IDEAS IN SCIENCE AS A FUNCTION OF AN INSERVICE PROGRAM FOCUSING ON STUDENT PRECONCEPTIONS

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Examining the impact of an inservice model on teacher understanding of selected science concepts is what this paper is about. The model places middle school science teachers in the role of action researches focusing on children's ideas about science (STAR-FOCIS). The model is designed to get teachers to restructure their own understanding of selected science concepts by having them concentrate on the structure, origin and evolution of their students' ideas. Concepts in topics from the life, earth and physical science served as the content focus and middle schools (grades 4-9) as the context for the study reported here. The broad question explored in this paper is: To what degree can teacher understanding of a science topic be enhanced by having teachers research (identify and analyze) the ideas of their students? The inservice experiences studied occurred in three distinct phases: an initial data collection phase, a data analysis phase, and an implementation and reflection phase. The purpose of the initial data collection phase was to ascertain what preconceptions students have about a particular science topic. Teachers collected these data via clinical interviews with their own students using student generated concept maps as an interview tool. Teachers then teamed with colleagues and a science expert in the data analysis phase to sort through and evaluate the scientific merit of the student frameworks. In the third phase of the inservice, teachers were directed to teach the target topic and pay particular attention to the ideas their students had at the start and how those ideas changed (or not) over the period of instruction. These ideas were evaluated by the teacher-expert teams at meetings held during the implementation/reflection phase.

THE UNIVERSITY - MUSEUM CONNECTION: A MODEL ELEMENTARY TEACHER TRAINING PARTNERSHIP

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It is often difficult to place pre-service elementary teachers in field situations where appropriate science education techniques are modeled. Too often, the experiences elementary education majors have in practicing science teaching methods are with other pre-service teachers and not with children. In addition, applying classroom management strategies in the context of appropriate science lessons while maintaining a positive classroom climate can be a traumatic experience for the novice teacher. Few teacher training programs provide settings which allow pre-service teachers to practice teaching science to children in an environment where both science content specialists and science education specialists can support the student at all times during the field experience. This symposium discusses case study findings for a setting where students are given the option of teaching specific science lessons in a museum setting. The museum organizes the lessons and content to be taught in the program. The students teach in the program, and provide feedback and analysis concerning the lesson designs and their effectiveness and developmental appropriateness for the children participating in the program. This symposium brings together museum personnel, the university science methods instructors, and students involved in the program to present the long term effects of this type of partnership and its implications and potential for elementary science methods courses.

THE PERCEPTION OF SCIENCE SKILLS BY COLLEGE METHODS INSTRUCTORS, EXPERIENCED, AND INEXPERIENCED SECONDARY CHEMISTRY TEACHERS FOR EFFECTIVE SECONDARY CHEMISTRY INSTRUCTION

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Science methods courses are designed by the science methods instructor to prepare the pre-service science teacher for effective science teaching upon graduation. The particular skills and methodologies within these courses should reflect the body of research within science education proven to promote learning. This study was undertaken to compare the skills which have been experienced by inexperienced chemistry teachers with experienced chemistry teachers within science methods courses taken for certification. Comparison was also made of the perceptions of science methods instructors as to the importance of skills currently being taught within their course. The analysis of the ranking of these skills by each group was also made to determine the overall importance of each skill as it contributes to effective chemistry teaching. Data for the study was collected by surveys sent to college science methods instructors, experienced teachers and inexperienced teachers. A total of 20 science skills targeted by the ChemSource project were included within the survey. Each skill was evaluated by the groups on Likert type scales as to the skills emphasis as presented within their methods course and to the emphasis which should be included within the course. The skills were then ranked in accordance with their significance in producing meaningful learning. The results of the survey indicate that there is a high degree of agreement among college faculty members teaching methods courses, inexperienced, and experienced chemistry teachers with regard to the skills presented in methods courses. The perception of inexperienced chemistry teachers with less than three year of experience closely correlate with science methods instructors as to the significance of the skills presented within science methods courses. Experienced teachers view of these skills as contained within the class differ the greatest from the other two groups. However, each group ranked those skills that foster a conceptual understanding of chemistry highest within the list. Differences exist among the groups as to the effectiveness of the particular skill in presenting the material. Methods instructors indicated that laboratory work and discussions are more appropriate in conceptual understanding, whereas experienced chemistry teachers preferred using demonstrations and drill and practice techniques. These differences in opinions may be explained as to the philosophical approaches of methods instructors to promote effective teaching and to lay a ground work of skills for pre-service science teachers necessary for successful teaching.

CUBE ACTIVITIES INTERVENTION TO IMPROVE SPATIAL ABILITY AMONG ELEMENTARY EDUCATION MAJORS

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For the past few decades, an increasing number of students in the United States have been diverting their interest from science into various other disciplines. This occurrence may stagnate the continuation of the country as a nation of technological advancement. It is possible that teachers are not aware of all possible factors for student success in science, factors which may impinge upon students' decisions to leave science. Current research identified one contributing factor as the failure to teach students the ability to reconstruct three-dimensional images or models of two-dimensional illustrations in their minds (Lord, 1985). Many students are deficient in their understanding of spatial relationships, also called spatial visualization. Thus, it is critical for science educators to recognize the importance of spatial visualization skills for success in academic science courses. For this study, spatial ability among elementary education majors (N = 24) from two Life and Environmental Science classes at East Carolina University was evaluated. The experimental design was developed as 2 x 2 factorial design. Four different treatments were developed, and subjects were randomly assigned to each treatment. One group received no treatment and served as the control group. The other treatments consisted of a video activity, a cube comparison test, and a combination of the two treatments with the video activity preceding the cube comparison test. The video activity consisted of a one minute animated illustration of a three dimensional cube (Cambre, Belland, and Baker, 1986). A second treatment was a cube comparison test created by the author, developed from a test taken from the Educational Testing Services Kit of Factor Referenced Cognitive Tests (Ekstrom, French, and Derman, 1976). A third treatment consisted of the interaction of the two previously mentioned treatments with the video activity preceding the cube comparison test. All four experimental groups received a pretest and posttest which were questions from the analytic and spatial portions of the Learning Style Profile (Leefe, 1988). In analysis of pretest and posttest scores, the data support an increase in all posttest scores from the initial pretest scores, with the group receiving both the video and cube test together increasing the most. In this study, improvements due to certain treatments have occurred, but the failure to detect significant differences could be the result of several factors. First, the test instrument used to measure improvement (analytic and spatial portions of the Learning Style Profile) may not have been sensitive enough nor long enough to detect any improvement. Secondly, the pretest scores were near the maximum level to begin with such that little room for improvement existed. Third, an insufficient number of subjects may have been assigned to each treatment. This pilot study indicates that acceleration of cube activity manipulation occurs as a result of a video pre-treatment.

A WAY TO RUN AN EFFECTIVE TRAINING MODEL FOR INSERVICE SCIENCE TEACHERS OF ELEMENTARY SCHOOLS IN TAIWAN

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The purpose of this study was to find out a relevant way to carry out an effective training model for an inservice elementary science teacher training program in Taiwan. The research consisted of two phases. The first phase was to use a survey questionnaire to probe what are the needs of today's inservice elementary science teachers. The second phase was to develop, implement and evaluate the effectiveness of the training program. One thousand, two hundred elementary science teachers were selected by stratified random sampling from all Taiwan elementary science teachers who were requested to respond to the questionnaire of "Needs assessment of inservice elementary science teacher training program". The results of the survey showed that the first two primary needs for elementary science teachers were the strength of their knowledge of science subject matter and the sufficient provision of teaching aids. Three hundred, eighty-three elementary science teachers participated in follow-up teacher training programs which consisted of ten activities. Nearly 97.4% of them responded that this training would be beneficial to their science teaching and 95.3% of them were confident of their science teaching through this training. Based on the findings and conclusions, this study provided an effective model for a teacher training program for educational administrators and teacher colleges.

GENERAL EDUCATION BIOLOGY COURSES, STUDENT CHARACTERISTICS, AND CRITICAL THINKING

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This study was designed to test the hypothesis that four general education biology courses promote critical thinking and to determine which form a suite of variables reflecting student characteristics correlated with students critical thinking ability. The courses studied were an Investigative Biology Laboratory course, An Evolutionary Biology course, an Environmental Biology course and a Human Nutrition course which differed in the extent to which assessment required more than memorization. The critical thinking ability of students was measured using Watson Glasser Critical Thinking Appraisal (WGCTA). The subjects of this study ranged from freshmen to senior college students. The results of the statistical analyses show that regardless of teaching and assessment techniques, the courses do not contribute to the critical thinking ability of the students. Among the nine principal components of students' characteristics, only the ACT component scores correlated positively and significantly with the WSCTA scores; college experience fails to promote critical thinking.

REPRESENTATION AND FEEDBACK IN THE FORMATION OF A PHYSICAL SCIENCE CONCEPT

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The main purposes of this empirical study were to determine 1) how high school students represent the physical phenomena of phase changes, 2) how they modify their representation of these physical phenomena to accommodate new observations, 3) what factors lead to students' difficulty in modifying representations, and 4) how the field-dependence-independence construct relates to the character of the models and receptivity to feedback. A video tape was prepared of five experiments which involved the phenomena of phase change under various conditions. An introductory question about solids, liquids and gases was asked to determine recall independent of context. Then for each experiment the subject was shown the apparatus and was asked what will happen when a certain procedure is carried out. He was also asked to justify his prediction. The subject then observed the experiment and was asked how the observed phenomena can be explained. The experimenter asked questions to clarify or expand on what was already indicated by the subject. The population was composed of above average high school students in a suburban high school. It was found that students' theories were often fragmented and "unscientific". When they differed from those of an expert, they fell into one or more than five categories. They were based on 1) macro level properties, 2) unacceptable scientific theories, 3) inappropriately applied theories, 4) internally inconsistent explanations, or 5) "rule" based justifications. The students generally did not use many molecular or "scientific object" level representations that were considered relevant. Subjects used more molecular representations than "scientific object" representation but this was often in conflict with an expert's representation. Although there wasn't a significant difference for the overall protocol, there was a significant difference between the groups for a section of the protocol. The ability to predict the outcome of an experiment ranged from 0 to 4.5 correct predictions. It was also found that there was a low correlation between the number of correct responses on the molecular level and predictions but a moderate correlation between the number of correct responses on the scientific object level and predictions.

DIAGNOSING PROCEDURAL SKILLS IN CLASSICAL GENETICS PROBLEM SOLVING

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Perhaps the most important aspect in any attempt to simulate intelligent tutoring is diagnosis. The results of certain diagnostic inquiries are integral in making tutoring decisions such as when and how to intervene with an ongoing tutorial session, what particular topic to pursue next, and other similar pedagogical inferences. Can we derive a reliable indicator of a (novice) student's performance, be it on a local or global level, depending on one's perspective? This questions is what we hope to shed some light on. Our study investigates a fuzzy approach towards the possibility of automating problem solving skills diagnosis. A mathematical structure called a *fuzzy cognitive map* is formulated to capture cognitive issues and the overall design of a proposed system is discussed. Initially funded by the National Science Foundation as part of the project "Computer Diagnosis of Faults in Genetics Problem Solving", classical genetics remains the intended test bed of our endeavor. But the underlying structures will be applicable for other diagnostic tasks as well. In this paper, we present our proposal for deriving a global representation of being a novice's knowledge state. Our formulations assume what Goldstein (1979) refers to as an *overlay* between expert and novice knowledge. A more localized scheme will be presented in an upcoming paper. The main point here is that we hope to be able to incorporate our diagnostic system approach into any existing (tutoring) system that requires such a feature. The global scheme we propose is derived from meta-level knowledge structures. These are configured to represent various intrinsic relations between the objects that comprise the knowledge base. Zadeh's (1965) *fuzzy sets theory* is used to deal with the uncertainty in modeling this cognitive task. The primary objectives of the study are: (a) to attempt to simulate human diagnosis of problem solving skills at a global level, thereby facilitating more localized approaches; (b) to formulate and develop an experimental system that will perform this diagnostic task of a tutoring system. No direct attempts will be made to develop a system that will possess the capability itself of intelligently solving the problems it presents. To do so would be to undertake a different research project of at least equal magnitude, or else to restrict the type of problems to more trivial. Our primary concern is the diagnostic task. This investigation is fundamentally based on current research in classical genetics problem solving by one of the authors. Our research currently concentrates on the identification, approximation and comparison of *chains-of-thought*. This will consolidate with our *fuzzy cognitive map* formulations to establish a more complete and reliable diagnostic scheme. We are maintaining our fuzzy approach to capture approximate reasoning schemes and hope to report more as we progress.

THE INFLUENCE OF LANGUAGE IN MIDDLE SCHOOL PROBLEM SOLVING

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In this study an attempt will be made to distinguish between the process of problem solving and term identification. The study is a pre-test post-test, three group design, one group being the control. The subjects are 118 seventh and eighth grade students in an upper middle class suburban public school near a small city in upstate New York. The reason for selecting this population is that this is the age of the initiation of rational thought. It is hypothesized that the difference between the means on a problem solving scale between two groups of students, one of which received instruction in using new vocabulary, will be statistically significant. Prior to the study, standard Scholastic Aptitude Test scores for mathematics, critical thinking, reading and reasoning will be obtained. Secondly, a valid critical thinking test, such as the Ennis-Weir Critical Thinking Essay Test will be administered to all of the students. A third instrument, to be developed by the researcher, consists of problems that the student will be asked to rewrite, omitting certain words. After the students have rewritten the problem he or she will be asked to solve the problem. The rewritten problem will then be scored. The scoring will give each subject a score in one of the following categories: Correct translation and correct solution, correct translation and incorrect solution, incorrect translation and correct solution and, incorrect translation and incorrect solution. The subjects will be randomly divided into three groups; each of these groups will receive a self contained pre-programmed package. The units will stress one of two possible input processes of problem solving. Both of these packages will be from previously published sources. They will consist of a series of reading and paper and pencil activities that will inform the student of various problem solving strategies. One set of materials will stress verbal problem solving. This set will encourage students to look up the definition of unfamiliar words, to write notes, to consider the meaning of the word in different contexts and write down their solutions in complete sentences. A second set of materials will stress the spatical aspect of problem solving. This group will be told to visualize the situation; to make diagrams while they read the problem and to attempt to visualize the problem. A third set of instructional material will have no relation to problem solving and will provide information on a disassociated topic, such as personal hygiene or class room safety. An unpaired t-test will be performed on the critical thinking scores to determine significant difference in means. From the rewrite test, a three by four matrix will be constructed, the three rows corresponding to the three test groups and the four rows representing the total scores. A two-way analysis of variance will be performed on the resulting matrix to determine if there is a between group score difference for any of the scoring variables.

RELATIONSHIPS AMONG PROBLEM SOLVING, STUDENT INTERACTION, AND THINKING SKILLS

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Students (N=42) were observed during five different life science problem solving activities. Student interactions and thinking skills were recorded in relation to the problem solving steps. A causal model was hypothesized and tested using path analysis procedures described by Pedhazur (1982). The hypothesized causal model was adjusted based on path coefficients of $p < .1$. The final causal model indicated that the problem solving steps had a greater influence on the use of thinking skills than student interactions, with data analysis influencing student interactions and thinking skills the greatest. However, student interactions fostered the use of thinking skills to solve problems that otherwise may not have been used. Student interactions appeared not to enhance the variety of thinking skills that all students used during problem solving. Students utilized focusing, analyzing, and evaluating skills during problem identification/refinement. Students may have failed to sufficiently plan to solve their problems and to evaluate their thinking data collecting procedures by not utilizing appropriate thinking skills. During data analysis students incorporated scientific knowledge into their explanations and evaluated their analysis process and conclusions.

MATHEMATICS - SCIENCE INTEGRATION PROJECT: A COLLABORATIVE RURAL SCHOOL EFFORT

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The Mathematics-Science Integration Project continued an on-going series of inservice workshops oriented towards the professional development of science teachers. The project, coordinated by a regional consortium, was funded by the Dwight D. Eisenhower Title IIA Higher Education Competitive Inservice Grants Program administered through the Bureau of Postsecondary Grants Administration within the New York State Education Department. A regional consortium, encompassing an area of approximately 4000 square miles, was comprised of the college, two BOCES units, a teacher center, and thirty-seven public school districts. The thirty-seven public school districts contained approximately 760 elementary school teachers and about 80 early secondary math and science teachers. The teachers served by this project included 75 elementary school teachers, 35 middle/junior high school teachers, and 38 secondary school teachers. The purpose of this study was (1) to provide a series of inservice workshops which emphasized mathematics and science training in the areas of problem solving, integration, and the use of technology in the teaching of math and science, (2) to provide a workshop to develop an awareness and a strategy for increasing student participation in science and mathematics with particular attention paid to underrepresented populations, and (3) to support the professional development of special project and to attend professional conferences. During the fall of 1989 there were two full day workshops, one addressing problem solving in mathematics and science (grades K-8) and one addressing the integration of mathematics and science (grades K-8). Also, teachers attended professional conferences on mathematics and science education. During the spring of 1990, a full day workshop was held related to the use of technology in science and mathematics classes (grades K-8). Additionally, a full day workshop for teachers (grades K-10) was held that dealt with increasing the number of women in science and mathematics. Teachers met also during this time to share the products developed as a result of conference attendance grants. Evaluation of the Mathematics-Science Integration Project was carried out through maintenance of administrative records and through formative and summative evaluations of the project. Formative evaluations were conducted at each session of the four workshops. Teacher development activities were evaluated via immediate teacher feedback and via follow-up studies. Summative program evaluation was conducted by an external evaluator via telephone and personal interviews of project staff, teacher center coordinator, and several math and science teachers. A form of stratified random sampling was used in an effort to enhance the ecological validity of the findings. As evidenced by participant responses to both the items providing ratings and through their written comments, the project would have to be considered highly successful. Participants received further training in selected areas as well as exposure to new topics and techniques. Participants found the instruction excellent. They acquired new knowledge that could be taken back to the classroom and their interest in pursuing the topics further was stimulated.

THE EFFECT OF VARIATION IN THE EXPANSION PHASE OF THE LEARNING CYCLE ON STUDENT CONCEPT ORGANIZATION AND APPLICATION

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Much research concerning the theoretical foundation and the related curricula of the learning cycle model has been generated over the past thirty years. That research has dealt primarily with the first two phases -- exploration and invention -- of the three phase cycle. The third phase, expansion, was developed to parallel the organization aspect of Piaget's mental functioning model. Little research has been done on the effect of the expansion phase on the student's ability to organize, generalize, and link the concept invented in the second phase with other related concepts. The present study was designed to examine the effect of variance in the expansion activities on student organization of the main idea of the investigation. The subjects in the study were students enrolled in a ninth grade physical science course in a midwestern city. The students were using a learning cycle curriculum developed for ninth grade students. Three investigations about machines were selected for the study. Three classes of students (n=25/class) were randomly assigned to one of two treatment groups and a control group. All the groups participated in the exploration and invention activities as written in the program. These activities were descriptive in scope; the students followed instructions for data collection, wrote the data in prepared data tables; and then participated in the class discussion about the data. Variance among the groups occurred in the form of the expansion activities in which they participated. Group 1 followed the script presented in the program; the data collection and analysis were at a descriptive level. Group 2 was given a question generated by the teachers and proceeded to design a laboratory experiment to answer the question. Group 3 engaged in a class discussion to generate plausible hypotheses and alternative hypotheses to explain a phenomenon observed in the exploration. The students then designed experiments to test those hypotheses. Concept mapping, specially designed concept application tests, and students interviews were selected to test the effect of the treatments on students concept application. All instruments were given in a pretest, posttest, post-posttest format. Equivalence among the groups was determined by administering Lawson's Classroom Test of Scientific Reasoning: Revised Edition. Data analyses have not yet been completed. Preliminary review of the data indicate that the students who engaged in the generation of hypotheses and/or the design of their own experiments exhibited a greater ability to discuss the relationships among, and links between, related concepts. The educational implications of this study include the need to rethink and perhaps redesign the expansion activities in existing learning cycle curricula.

A PATH ANALYTICAL MODEL OF VARIABLES THAT INFLUENCE SCIENCE AND CHEMISTRY TEACHING SELF-EFFICACY AND OUTCOME EXPECTANCY IN MIDDLE SCHOOL SCIENCE TEACHERS

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Path analytical models based on a theoretical framework developed from the theories of Albert Bandura were constructed to determine factors that influence self-efficacy and outcome expectancy in both science and chemistry teaching for middle school science teachers. It was hypothesized that teaching chemistry in a general science curriculum at the middle school level was analogous to teaching science in the general elementary curriculum. Factors initially hypothesized to influence science and chemistry teaching self-efficacy were coursework with laboratory experiences, science methods courses, teaching experiences and other work experience not related to teaching. Outcome expectancies were hypothesized to be influenced by self-efficacy and a variety of variables that cluster into three groups, student variables, family variables and external variables. Instruments measuring science and chemistry teaching self-efficacy and outcome expectancy were modified from instruments developed by Riggs (1988). Two questionnaires, based on current literature, were developed. One probed teacher backgrounds; the other explored teacher belief systems for student learning. The participants were 105 middle school science teachers in a large urban midwestern school. Data were analyzed via structural equation modeling and t-test. Findings indicated that teachers' self-efficacy was not a determinant of outcome expectancy, therefore, separate path models were analyzed for self-efficacy and outcome expectancy in both science and chemistry teaching. Chemistry teaching self-efficacy is different from science teaching self-efficacy for the middle school science teachers in this study. However, both are influenced by teachers' past experiences. Coursework with laboratory experience had a greater effect on the development of self-efficacy in these areas than did teaching experience, but the external variables of district level community support also play a role. Teachers' expectations for student learning are based to some extent on external variables connected with the school but also on variables associated with students' families and each student as an individual. Teachers with high chemistry teaching self-efficacy have characteristics important to effective chemistry teaching. Middle school science teachers perceive certain external variables to be more lacking for chemistry teaching than for science teaching.

AN INVESTIGATION OF COGNITIVE DEVELOPMENT, ATTITUDES IN THE SCIENCES AND ACHIEVEMENT ON MISSOURI CORE COMPETENCIES

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The purpose of this study was three fold. It was to determine whether students taught using an inquiry learning cycle would show a significant improvement in formal reasoning, attitudes toward science, and achievement in mastery of factual and conceptual science subject matter (declarative knowledge) compared to those students receiving instruction by the traditional method. A twenty five question Likert survey (modified from Simpson and Troost, 1982) and the Test of Logical Thinking (Tobin and Capie, 1981) were used to determine student attitudes and formal reasoning skills. Learning cycles units using the Madeline Hunter delivery style and traditional instructional materials were designed to analyze declarative knowledge (science content). A test of Missouri state core competencies was developed to determine achievement in declarative knowledge (science content) and process skills. Five hundred seventh and eighth grade students participated in the study. Pretest and posttests were administered for each assessment tool. The experimental period was eight weeks. Instructional units were taught by four experienced science teachers, each teacher teaching six classes. Approximately half of the classes for each of the instructors was taught by the learning cycles method and the other three classes were taught using the traditional approach. The teaching method for each class was randomly assigned. Statistical analysis by principal components and canonical correlations show evidence that the learning cycles method promotes more positive attitudes towards science. The findings do not show significant effects on the improvement of formal reasoning skills or declarative knowledge. Additional investigation suggests that in this study, attitudes and prior skills affect achievement (learning), but of the two variables, prior skills are the greater influence and account for the largest amount of variance in learning.

CHILDREN AND STEREOTYPES: MODIFYING THE IMAGE OF SCIENTIST

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It has been well documented that both children and adults develop and have stereotypic images of a scientist. Children as young as five find difficulty in associating the term doctor or scientist with "female". This image appears to transcend cultural bounds. It is as likely for children with a hispanic or arabic ethnicity to have a stereotypic image of a scientist as it is for children raised with an american heritage. Little research has been done looking at specific scientific disciplines and the "image" children from diverse ethnic backgrounds have concerning those disciplines or their own participation in those disciplines as adults. This preliminary research explores the relationship between first, third and fifth graders notions of specific science careers and personal ability to accomplish the tasks associated with those careers. Sample classrooms were asked initially to draw scientists associated with the specific topics being learned in science class and write paragraphs concerning their personal ability to "be" that kind of scientist. Teachers specifically intervened with role models and tasks identified as what that particular scientist accomplished "on the job". Specific teaching lasted from one to three weeks. Although analysis is not complete, it appears that while the generic "image of a scientist" as male, with a white lab coat and specific tools did not change significantly, children at all three levels (first, third and fifth grade) perceived the specific discipline scientists as something other than the stereotypic image. Further, particularly at the fifth grade level, students were able to analyze and discuss their personal abilities and personal "fit" to the tasks associated with the specific science disciplines. This indicates that perhaps our concern over what children perceive about scientists in general, may not be as important as the personal classroom experiences which build their individual conceptual framework.

THE EFFECT OF GENDER, ETHNICITY, SOCIOECONOMIC STATUS AND STUDY HABITS ON ATTITUDE AND ACHIEVEMENT IN A SAMPLE OF AT-RICK URBAN SECONDARY SCIENCE STUDENTS

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Relationships between gender, ethnicity, socioeconomic status, study habit and attitudes and achievement in the secondary science classroom were investigated. The sample comprised 585 secondary students in grades nine through twelve in four public and three private schools in a large urban community with a high percentage of at-risk students. Other variables considered included college plans, time spent on homework, and time spent viewing television. Results indicated a significant correspondence between ethnicity, socioecomonic status and attitude and achievement in science. College plans, time spent on homework and time spent viewing television appeared to some extent to influence student achievement, attitude and motivation in the science classroom. Significant differences were not found between the public and private schools investigated.

THE IMPORTANCE OF PLANNING IN ACHIEVING AN EQUITABLE SCIENCE CLASSROOM

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Researchers have studied science classrooms and have defined common strategies and practices that can help create an equitable classroom environment. One key aspect is that teachers need to minimize the time they spend lecturing and use other teaching strategies such as small group work discussions, and cooperative learning as alternatives. However, for student teachers, using these alternative teaching strategies may require more planning than lecture-oriented lessons. The purpose of this study was to determine if high school biology student teachers could transfer learned equitable teaching strategies to actual teaching and the importance of lesson planning in the implementation of those strategies. Both qualitative and quantitative data sources were collected, from a range of sources including preservice teachers, cooperating teachers, and high school students, and using a variety of techniques such as the content analysis of lesson plans, responses to questions regarding the psychosocial environment scales, interviews, and classroom observations. Results showed that student teachers could transfer learned equitable teaching into actual teaching practice. However, they were more successful in achieving the transfer if they had well planned lessons. Student teachers who were poor planners tended to use whole class teaching activities and rely on male target students during class discussions. Consequently, they created a more competitive rather than cooperative learning environment, compared with their peers who were better planners.

ENHANCING SCIENCE ACHIEVEMENT AND ATTITUDES IN LIMITED ENGLISH PROFICIENT STUDENTS

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To strengthen the content of instruction and to provide a high quality learning environment for LEPs, the researchers have developed an instructional model entitled Cooperative Environment for Language Acquisition Through Scientific Inquiry (CELSI). This model incorporates three research-based approaches: (a) cooperative learning, (b) cognitive mapping, and (c) science inquiry. The purpose of the present study is to measure the effectiveness of the CELSI model in improving science achievement and attitudes about science learning of mainstreamed LEP students. The participants in this study consisted of 108 fourth-grade LEP students. These students were enrolled in six inner city schools from a major metropolitan area in the Southwestern United States. The control group consisted of forty-six students: 20 Hispanics, 2 Blacks, 23 Anglos and 1 Other. Seventeen were males and 29 females. The experimental group had 62 students: 49 Hispanics, 12 Anglos, and 1 Other. Thirty-five were male and 27 female. Independent $\underline{t}$-tests were used to analyze the gain scores of each individual in both groups. The findings support the value of the CELSI program in that the group exposed to CELSI instruction ($\underline{M} = 8.16$; $\underline{df} = 106$) showed a greater achievement gain ($\underline{p} < .05$) than the control group ($\underline{M} = 6.99$; $\underline{df} = 106$) in standardized measures of science achievement. The attitude measure, using two matched groups of forty students, indicates statistically significant differences ($\underline{p} < .001$) between the CELSI group ($\underline{M} = 13.93$; $\underline{df} = 39$) and the control group ($\underline{M} = 11.75$; $\underline{df} = 39$). From these findings, we concluded that the CELSI model is beneficial for LEP students in improving science achievement and attitudes towards science learning. Additional research is currently underway to measure CELSI's long-term effectiveness.

A QUALITATIVE STUDY OF THE INTERACTIONS OF ELEMENTARY STUDENTS AND TEACHERS WITH FOSS - FULL OPTION SCIENCE SYSTEM

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A qualitative case study of five teachers in three rural Nebraska school districts was used to study the affects of a "second generation" hands-on science curriculum Full Option Science System (FOSS) on teacher and student behavior and attitudes, the use of collaborative student groupings in conjunction with a hands-on curriculum and the curriculum implementation processes involved in each of the three districts. A naturalistic paradigm was used to qualitatively investigate the perceptions of key actors involved in the implementation of the FOSS program. A multi-site, multi-method design was used. The researcher served as the primary data collection and analysis instrument. Extensive field notes were gathered in the natural setting of the elementary classroom. Journals, interviews, artifacts, and reflective field notes were additional data sources for this study. Data analysis involved the use of five analytical procedures. Analytical induction, constant comparison, typological analysis, enumeration, and standardized observation protocols were used to compare, induce, derive, and enrich themes, categories, and propositions from the data. Preliminary findings suggest the teaching behavior of teachers were most affected by the combined influence of the availability of equipment and materials and the positive attitudes of their students. The difficulties encountered in using collaborative groupings of students were complex and not easily resolved. Training and implementation processes varied from district to district.

IMPROVING SCIENCE TEACHING IN ELEMENTARY SCHOOLS: A RESEARCH PROGRAM BASED UPON COGNITIVE SCIENCE AND INSTRUCTIONAL TECHNOLOGY

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The dual definition of science as a body of knowledge to be understood and as a process for acquiring new knowledge presents a particularly difficult problem for science educators in terms of elementary science methods courses and inservice teachers training (Linn, 1987). From both perspectives, the mastery of core science concepts is an important prerequisite for effective teacher preparation and practice. Just as the understanding of core science concepts is required for mastery of effective science teaching skills (e.g., process skills activities, inquiry questioning, concept development), so must the science knowledge of elementary teachers be considered when designing research to advance the theory and practice of science teaching. This paper described results and work-in-progress of a multi-year program of research addressing the improvement of science instruction in elementary schools. The strategy of the research program is to integrate a general constructivist perspective from science education (Lawson, Abraham, & Renner, 1989; Shymansky ,1989; Tobin, 1990) with those of two rapidly developing and highly complementary disciplines: (a) cognitive science (Posner, 1989; Resnick, 1989), and (b) instructional technology (Gagne, 1987; Larkin, Scheftic, & Chaby, 1990; Reif, 1989). In describing the strategy, the paper overviews the rationale and empirical findings from two complementary categories of research applications conducted within the research program over the past five years. The first of the two research categories focuses upon the improvement of the science teaching process itself through a series of studies that (a) investigate the importance of preservice and inservice teachers' understanding of science concepts upon their attitudes toward and confidence in science and science teaching, including their capability to learn and use science-specific teaching skills in classroom settings and (b) explore training models through which preservice and inservice teachers can learn to apply instructional design principles to improve classroom instruction. The second of the two research categories emphasizes the qualitative enhancement of students achievement in elementary school classrooms in both science and basic skills through a series of studies that (a) implement organizational changes in the classroom curriculum to integrate basic skills learning within an expanded science curriculum and (b) use specific technology-based videodisc programs in science and mathematics within an elementary science program. In presenting research findings, the paper also discusses how the application of research and theory from cognitive science and instructional technology to problems in science education have guided the "two-pronged" research program.

GENDER AND RACIAL INTERACTIVE DIFFERENCES IN UNSTRUCTURED GROUP WORK

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The purpose of this study was to examine the internal dynamics of cooperative learning groups. Teachers from seven intermediate grade level classrooms had four months of training in cooperative learning strategies. Twenty-eight students, grouped heterogeneously for sex and race and homogeneously for their ability in science, were selected for observation and analysis. They were video-taped while working in a cooperative learning science lesson and these interactions were classified into five roles (i.e., Idea Person, Reflector, Facilitator, Cheerleader, and Blocker) using systematic observation procedures; the amount of time they handled the science equipment was also recorded. In general, students' behaviors were extremely positive (i.e., there were more than four times more positive behaviors than negative behavior). Further, in reviewing the positive behaviors, students assumed the idea person role more than four times as much as any of the other roles. Differences in behaviors between whites and blacks and between male and female students were observed. The amount of performance of the facilitator role differed for males and females significantly. Specifically, the females encouraged other members to participate in the activity significantly more than the males did. There was a trend in the number of times the equipment (clay) was handled; the males handled it more than the females as a function of race.

THE IMPACT OF TRANSITION FROM JUNIOR HIGHS TO MIDDLE SCHOOLS ON SCIENCE PROGRAMS

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Nationally many middle level schools are changing from a traditional junior high school structure (grade 7-9) to middle schools (grades 6-8). This case study examines the impact of middle school organizational changes, that occurred as a large school system converted from junior high schools to middle schools, on science teachers and science instruction. A qualitative case study methodology utilizing structured interviews was conducted to determine the time available for science instruction, the science content of interdisciplinary units, science equipment transfer and storage, pre- and inservice science education of teachers and science leadership issues. The results of the study revealed that sixth grade teachers had completed fewer courses in science and had serious problems accessing science equipment and supplies. Seventh and eighth grade teachers had little understanding of the sixth grade curriculum or the needs of the sixth grade science teachers. More time was available under the middle school organization for science instruction and most of the interdisciplinary units taught had strong science components. Funding and leadership issues for science may require special attention with the change in organization from department to teams within the middle school.

THE IOWA CHAUTAUQUA PROGRAM

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The Iowa Chautauqua Program is an in-service education model that assists schools and teachers with moves to STS emphases for K-12 science. The model consists of : The Iowa Chautauqua Model which can be described with several features. In chronological order these include: (1) a two-week leadership conference for 25 of the most successful teachers from previous years who wanted to become a part of the instructional team for future workshops; (2) a two-week summer workshop at each new site for 30 new teachers electing to try Science/Technology/Society (STS) modules and strategies in which the workshop provides experience with STS (teachers as students) and time to plan a five-day STS unit to be used with students in the fall; (3) a two and one-half day Fall short course for 30-50 teachers (including the 30 enrolled during the summer) where the focus is on developing a month long STS module and an extensive assessment plan; (4) an interim communication with central staff, lead teachers, and fellow participants, including a newsletter, special memoranda, monthly telephone contacts, and school/classroom visits; and (5) a two and one-half day spring short course for the same 30-50 teachers who participated in the fall focuses on reports by participants of their STS experience and the results of the assessment program. The program has been successful in stimulating nearly 1,800 teachers to implement STS material and teaching strategies during the past eight years. The program has been successful in stimulating changes in teachers attitudes about their science teaching. They become more enthusiastic, more willing to admit to not knowing, more willing to involve students in the planning and doing of science and, more willing to use community and human resources. Changes in student growth are also observed with moves to STS. Students do not learn more concepts--but there is evidence that they learn them better (information is retained and more useful). Students also show major increases in their use of science process skills. They can demonstrate use of such concepts and processes in new situations. Students also grow dramatically in terms of creativity skills, specifically the quantity and quality of questions generated, courses suggested, and consequences predicted. And, most dramatic of all is their increase in terms of positive attitude. The Chautauqua Program has encouraged a move to coordinated STS programs at given grade levels and across grade levels. Iowa has been selected as one of the NSTA Scope, Sequence, and Coordination (SS&C) Centers. This new effort means working with four school districts as they develop new modules utilizing the Project 2061 concept themes. Current work focuses on grades 6 and 7. The plan is to develop an integrated STS Scope and Sequence for the grade 6-12 continuum for all students.

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PARTICIPATION IN SCHOOL SCIENCE: A SYNTHESIS OF RECENT RESEARCH

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The synthesis of the literature was initiated to examine the wealth of research that has emerged in recent years on the topic of participation in science. Sixty five studies covering research during the 1970's and 80's were identified using the ERIC system and Dissertations Abstracts. An examination of these reports resulted in the grouping of the research into three categories. First, a picture of the current enrollment in school science was produced from the studies that describe the number of students that continue in science. Second, studies that infer relationships about the variables related to continued participation in science were synthesized to characterize avenues for possible interventions. Third, studies that have conducted interventions in students participation in science provided examples and insights into the future direction for research. One major finding from the study is the apparent strong and consistent relationship "science -self" variables have to participation in science. Though there is a lack of consistency in the manner of definition and measurement of this construct, the relationship is indicated across a wide range of reports. This review has been conducted in an attempt to provide a synthesis of information on elective student participation in school science. It is believed that this synthesis provides important support and direction to the profession of science education's goal of scientific literacy for the general public.

DECLINES IN STUDENT ACHIEVEMENT IN SCIENCE: IMPLICATIONS FOR PUBLIC EDUCATION

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During the 1960s and 1970s, new methods of instruction and major innovative science curricula were introduced into public schools in the United States. Federal funds were used to provide science teachers with additional training and funding for public education increased sharply. Nevertheless, student achievement and interest in science has generally declined since 1963. By the mid-1970s, declines in student achievement led educators to voice concern about the state of public schools in the United States. By 1980 these concerns were replaced by warnings of a crisis in education. In 1983 the warnings were confirmed when the National Commission on Excellence in Education released the report, *A Nation at Risk*. This report sparked nation-wide educational reforms. Despite these reforms, however, national and international indicators of science and mathematics performance of students in the United States has shown little improvement. A major difficulty in trying to improve the level of achievement in public schools is that there is little consensus on the nature of the causes or the solution to the current educational problems. Some of the national educational reports have concluded that teacher training and salaries are the key to higher student science achievement. Certain educational critics claim that the solution involves greater emphasis on teaching higher order thinking skills. Still others claim that major curricula reforms are needed. The variety and range of proposed solutions have grown as the inability of schools to restore science achievement has become more evident. There is a critical need to understand the causes for the current crisis in science education in order to find solutions. Unless the principal factors responsible for declining science achievement are isolated, time, effort, and large amounts of money may be wasted trying to fix illusionary problems. This research focused on changes in four of the key variables related to science achievement--teachers, students, curricula, and school goals. The research examined (a) meta-analyses of the effectiveness of the innovative science curricula on students achievement, (b) research on changes in teacher and student characteristics during the last 30 years, (c) the educational literature on changes in the goals of public education during this same period and (d) changes in student achievement. The results of the research suggest that the recent declines in science achievement are related to changes in student motivation and to changes in school goals. Furthermore, the data indicates that contrary to the claims of some of the recent educational reports, teachers and curricula have improved steadily over the last three decades. The hypotheses developed from this research lead to educational solutions that are very different from many of the recent reforms implemented in schools. The research also suggests that many of the proposed solutions will have only a minimal effect on student achievement. The paper concludes with a discussion of the prospects of improving the level of science achievement in public schools, as well as a discussion of the implications of the findings of this research for public education.

FORMAT FOR SUCCESSFUL BIOLOGY LABORATORIES: A RESEARCH BASED MODEL

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Science is a process by which we increase our understanding of the universe. In most all schools across America, the process of science has been replaced with lectures, rote learning, and laboratory exercises commonly termed "cookbook labs", (Hurd et. al., 1980). The rationale used for maintaining and teaching the "science as a body of knowledge" approach appears to be very similar whether trying to incorporate inquiry learning (Costenson and Lawson, 1986), or science-technology-society (STS) education (Michener and Anderson, 1989). This study develops a format for incorporating research-based learning strategies (science as a process) into the "cookbook" exercises found in typical laboratory materials. The format is developed from a synthesis of research findings that identify the successful aspects of laboratory exercises. This format allows teachers to alter "cookbook" laboratory materials so that students, over a wide range of learning levels, would be able to experience science as a process. Established curricula would need little alteration when implementing the format for science as a process laboratory exercise. The format is applicable over a wide range of science disciplines. The use of this format to convert traditional laboratory materials and the cost to convert typical curriculum materials is discussed.

THE NATURE OF A BIOTECHNOLOGY CURRICULUM AS PERCEIVED BY BIOTECHNOLOGY MAJORS, PROFESSORS, AND INDUSTRY

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Biotechnology is a relatively new curriculum within the sciences. In many instances, biotechnology is a recombining of many existing courses with emphasis on application for new technologies. The educational philosophy that directs biotechnology has been moving toward careerism. Professors, students, and industrial scientists have all come together to many universities to participate in a new discipline. This study utilized a structured interview, face-to-face or telephone, with forty-five volunteers that were either biotechnology majors, professors, or industrial scientists. Each volunteer was recorded verbatim on answers to a preconstructed questionnaire. The questionnaire asked seven questions which addressed the same question for each group The questions were directed to one's philosophy on the biotechnology curriculum. This study reports assertions in the categories of 1) what were the groups' philosophies on the rationale of a biotechnology curriculum, 2) who had the greatest influence on structuring a biotechnology curriculum, 3) trends in biotechnology curriculum, and 4) what recommendations can be made for improving the process of curriculum development in applied science areas.

FORMAT OR FORMAZE? WHAT NATURALISTIC RESEARCH REVEALS ABOUT HOW COLLEGE STUDENTS CONDUCT AND COMPOSE ORIGINAL RESEARCH

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In a three year writing protocol study, a focused pair research team examined how upper-level college biology students conducted and composed original science research. This naturalist research examined a single assignment in which each student compared two commercially available products to determine which was the better product. The assignment required that each biology major establish four quantifiable criteria to determine the better product. To succeed, students needed to demonstrate that they could design an experiment, control variables, define operationally and interpret data. After they had conducted the research, they were required to write research reports that included: Title, Introduction, Methods and Materials, Results, and Conclusions. In Spring 1983, as the biology instructor taught an advanced writing course for biology majors, the students kept a writer's log and talked into tape recorders as they composed. These materials were turned into a writing instructor from another college; students were assured that this data would not be examined until the next fall. In addition, the researchers collected the students' notes, rough drafts, preliminary illustrations, peer group tapes, final copies of the original research and other ethnographic data about the students. After examining the data and changing some classroom procedures, the researchers replicated the study in 1986. In both years, 13 students were actively engaged in the class during the time of the assignment and 11 students turned in usable data. Five areas of difficulties were documented: (1) Students had poorly designed experiments. (2) Students had difficulty with the scientific format. (3) Students could not define operationally. (4) Students had little sense of audience or self. (5) Students had difficulty interpreting data. This presentation focuses on the difficulties students had with format. (1) Students fail to distinguish the order of composing from the order of format; in 1983, 10 of the 11 students tried to compose the introduction before doing the research. (2) Students tried to write the report section by section rather than writing a rough draft and putting it into sections. (3) Many students used a poor heuristic; they did the research and then went back to write about it. More successful students wrote out the "Methods and Materials" section before doing the research. (4) Students did not conduct pilots; therefore, they had many organizational difficulties both in designing experiments and identifying sections within format. In addition, data indicates students reasoned that text with numbers must go in RESULTS, that there should be transitions from section to section, and that organization among sections was unnecessary. The 1986 data documents that teacher knowledge of difficulties and changes in activities can significantly improve class performance.

THE INFLUENCE OF PERSONAL FACTORS INCLUDING RACIAL CLASSIFICATION ON COLLEGE GENERAL EDUCATION SCIENCE ACHIEVEMENT: A MULTIPLE REGRESSION STUDY MODEL

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During the past two decades, significant effort has been put forth by the National Science Foundation and related governmental agencies to improve minority participation in science, yet the record shows a continuing pattern of under-representation. Such evidence suggests the problem to be greater than legal opportunity alone. Increased minority participation in science ultimately depends upon increased enrollment in college science courses and programs of study. This research project was designed to study two of four factors cited by "Science Education for the Eighties: Minority Participation," as important for improving minority participation and enrollment in college science -- attitude toward science and inadequate preparation. The study centered around analyses of components of a General Education Science Achievement Model developed by the author. The model suggests that achievement determined by course grade in general education science may be directly or indirectly influenced by students' (1) personal characteristics, e.g., race, gender, age, (2) preferences and understanding of science resulting from previous positive or negative experiences, and (3) native knowledge of the nature of science generally resulting from school experiences. In other words, the model is a microcognition explanation of achievement behavior resulting from the sum total of the person's experiences related to general education science courses. Three survey instruments were selected and/or designed to pursue analysis of model components. The study population included both minority and nonminority students registered in general education science courses at St. Cloud State University, a comprehensive state university of approximately 17,000 students in central Minnesota. Data were statistically analyzed using a multiple regression procedure. One-way relationships between each component of the model were analyzed in addition to the interrelationship of all the model components together. Nineteen predictor variables including racial classification were analyzed to determine their relationship with other model components and course grade. Results indicated the five most important predictor variables of achievement determined by course grade in stepwise order were: (1) business majors, (2) student's gender, (3) student's attitude toward science, (4) age of the student, (5) size of the community where students had been raised. In the analysis of the overall achievement model, separate racial categories, e.g., Asian, Hispanic, were not strong predictors of course grade achievement. When racial classification data were combined into Affirmative Action minority-nonminority categories for analysis, race was still not a strong predictor of achievement. Data are not conclusive nor can generalization be made until larger populations are sampled and analyses completed.

INTERNATIONAL HISTORY, PHILOSOPHY AND SCIENCE TEACHING GROUP - A DISCUSSION

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The purpose of this round table discussion is to provide information for NARST members interested in attending or participating in the 2nd International History, Philosophy, and Science Teaching Conference to be held on May 11 - 15, 1992 at Queen's University in Kingston, Ontario, Canada. Michael Matthews, Newsletter Editor, Richard Duschl, Advisory Committee Member and Skip Hill and/or Brian Andrews, Conference local organizing committee will meet with individuals to discuss activities of the newly formed International History, Philosophy and Science Teaching Group. The 1st conference of the Group has produced a significant body of literature relevant to the preparation of teachers and to the design of science curriculum. Information about acquiring this literature as well as reviews of the research in the field prepared by Matthews (Studies in Science Education, Vol 18, 1990, pps. 25-51) and being prepared by Duschl (Chapter in Handbook of Research on Science Teaching and Learning) will be shared with participants. The goal is to provide useful information about proposal and manuscript preparation for scholars interested in presenting at the next conference.

TEACHING METHODS COURSES IN SCIENCE EDUCATION

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Many junior college and university faculty, severely subjected to the "publish or perish" nemesis, have limited time and effort for the development of quality teaching training programs in science. It is crucial that science educators be given the knowledge, and the opportunity, to improve their existing science methods courses through exposure to innovative models, ideas, and materials. The purpose of this proposed round table discussion is to bring together science education researchers, who also teach, to share ideas, models, strategies, and materials that they have used successfully in their science methods course work. The discussion will focus on: (1) the practice of teacher-researcher skills such as making classroom observations and conducting student interviews; (2) peer-coaching interactions and self-evaluation exercises; (3) innovative assessment techniques; (4) strategies that apply instructional technology; and (5) activities for integrating current models of teaching with appropriate content. It is our intent to establish a national cadre of science education faculty who will continue to share ideas concerning methods course instruction throughout the year. We will explore the possibility of using an electronic bulletin board, such as BITNET. All participants are encouraged to bring copies of activities, syllabi, course frameworks and other interesting materials.

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AGE DISTRIBUTION OF PUBLIC SECONDARY SCIENCE TEACHERS: POSSIBLE RELATIONSHIPS WITH SCIENCE DISCIPLINE, SCHOOL SIZE, AND POVERTY LEVEL VARIABLES

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This study represents a methodical approach to the issue of supply and demand interactions or employment patterns among science teachers at the secondary level. The intent of the study is to provide demographic information related to the individuals currently composing the science teaching corps in Kansas. The approach could be used in any area where comparable data is available. Cohort distribution shapes and differences are investigated to assess the impact of two school setting variables, school size and eligibility for free lunch program participation, and an individual science discipline preparation variable, as well as the factor of time. The age distributions in the low and medium poverty settings tend to have uni-modal age distributions, while the high poverty settings tend to have bi- or tri-modal age distributions. Significant changes are found in the age distribution of Kansas secondary science teachers during the 1985-86 to 1989-90 time period. The 1989-90 cohort distributions also show significant differences related to the science discipline in which a teacher is assigned classes. Science teachers in large, low poverty school settings are permitted the greatest degree of specialization; they tend to be assigned classes in a significantly lower number of disciplines than are other groups of teachers. Small school teachers are assigned to teach in a significantly higher number of disciplines than are other groups, regardless of the poverty level. However, teachers in large, high poverty schools look much like small school teachers; they are assigned to teach classes in a significantly higher number of disciplines than are other groups of teachers. Teachers in small schools are much more likely to be assigned to teach classes in both science and non-science disciplines than other groups of teachers. The findings from this study expose the conflict between the growing pressure to require more specialize, in depth preparation of our science teachers while also preparing some of them to serve the needs of small schools. A possible channel for resolution of the conflict is to seek alternate modes of instructional delivery.

KNOWLEDGE DEVELOPED BY A HIGH SCHOOL TEACHER ENGAGED IN PHYSICS RESEARCH

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Numerous research studies and national reports have publicized the problems in American science education. There are many efforts underway to address these problems. This proposal describes one such effort driven by a concern for enhancing physics teachers' content and pedagogical content knowledge by having them work as part of an advanced physics research team at a major research institution. For the past three years, the University has provided opportunities for students from a variety of colleges around the state to work with University faculty members and researchers on funded research projects in physics. The purpose of the program was to expose very capable students to the world of physics research, first hand, in an effort to encourage them to pursue graduate study and careers in physics. That project was deemed a success. The research described in this proposal was predicated on the belief that such research experiences also would be beneficial to high school physics teachers. This project was designed to put a high school physics teacher through the summer program with the college science majors and assess the benefits to the physics teacher. Ethnographic research techniques were employed for this study, which was initiated in the Summer, 1990. The teacher was interviewed before, during, and after the Summer, 1990 research experience. The information gained to date in this initial field trail was important for several reasons. First, the teacher claimed that he benefitted greatly from his participation in the summer research program. He concluded that he has new knowledge and enthusiasm, and that these will enhance his teaching of physics. This indicates that such an experience can be very valuable for high school teachers. Secondly, the project established a productive working relationship between the University's Department of Physics and School of Education in the common quest for the improvement of Research Experience for Teachers (RET) program, which will be implemented next summer. Continued on an annual basis this will, hopefully, be effective in meeting the needs of participating high school science teachers.

A SURVEY OF THE DIFFERENCES BETWEEN SCIENCE FAIR TEACHER - SPONSORS AND NONSPONSORS AT MIDDLE & HIGH SCHOOL LEVELS

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Science fairs have been a part of the educational system in the United States for the last 60 years. Science fairs might be defined as the visual, written and oral presentation of an independent, individual original student investigation. Last year, according to the annual Science Service report (1989), 31,652 elementary, 62,774 middle school, and 105,324 high school students participated in regional science fairs. These figures exclude those students that participated at the school, county, or district levels. Even though the educational worth of science fairs has been questioned in numerous articles, very little research has been conducted in this area. The purpose of this study is to investigate the group differences and similarities between science fair teacher - sponsors and teacher - nonsponsors of students in grades 6-12. Science fair sponsors are those individuals who involve their students in science projects, and who then serve as sponsors for those students in a district or regional fair. Nonsponsors are those individuals who do neither of those activities. The three areas of focus will be personal biographical information, physical resources available, and administrative/peer support provided to these teachers. Characteristics of teachers will be divided into categories based on various criteria. Sub-levels will be established on the basis of the method of collection such as the Likert scale, ratio scale, and ranking. Face validity for the questionnaire will be established by a panel of experts and by a pilot study at the 1991 Georgia Science and Engineering Fair. Reliability for the instrument will be determined by using a test-retest method. The target population for this research study will include science teachers in Georgia who teach in grades 6-12. Geographical areas will be used to divide the state into homogenous groupings. School and student characteristics between schools, within a geographic area, should be very similar to help reduce variability. Each high school and middle school will be identified as sponsors or non-sponsors of science fair projects. Two high schools and two middle schools of each type, sponsors vs. non-sponsors, will be selected from each geographic area. The number of teachers that sponsor science fair projects will be determined and included in the sample along with an equal number of non-sponsors from the second school in that respective area. A contact person at each school will be trained in the administration of the instrument. Dates in the spring and fall will be selected for the administration of the instrument to all teachers. Three separate applications of the questionnaire will be used to increase the level of response. Each questionnaire item will be recorded according to its subgroup into a data base. Each subgroup will be analyzed to produce a summary of the responses. Correlations coefficients will be calculated whenever possible on Likert scale items. Descriptive statistics such as mean, mode, median, variance, range, and standard deviation will be determined for numerical responses. An appendix will be used to show the entire data base and tables will include summaries of the trends. The data collected in this study may help establish important relationships between science fairs and teachers.

EVOLUTION OF ATOMIC THEORY: CONTRASTING REPRESENTATION IN INSTRUCTIONAL TEXTS WITH KNOWLEDGE IN SCIENTIFIC FIELD

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Science education in particular has been severely criticized by leaders of government, industry, and academe. Recent research findings, as well as national survey results indicate that science instruction is dominated by textbooks. An analytic study of the evolution of ideas presented in general chemistry textbooks was undertaken in order to help affect an improvement in future science instruction. The study addressed the following questions: How is knowledge represented in textbooks? How does this form of representation compare to the scientist's? How has each evolved when viewed individually and with respect to each other? When were new ideas published in the scientific literature and how does this compare to the time of their appearance in textbooks? The research was conducted in case study form. The evolution of atomic theory was traced from 1900 to 1980. Two primary sources were used, general chemistry textbooks and scientific literature. Two significant results were found. First, there was a considerable lag noted between the time new knowledge was accepted in the field and its inclusion in texts. Secondly, misrepresentation of new knowledge was found to be promulgated by utilitarian educational purposes. In light of these finding, educators can question the suitability and perhaps suspect the near obsolescence of the textbook as an instructional tool.

RISK-TAKING AND LEADERSHIP ROLES FOR TEACHERS IN IMPLEMENTING CURRICULUM CHANGES

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Consisting of upwards of twelve local school districts, the Oregon Museum of Science and Industry (OMSI), the Lewis & Clark College, and the Oregon Consortium for Quality Science and Mathematics Education (OCQSME) have, for three years, pooled Eisenhower Act (Title II) allocations and implemented a plan for staff development and curriculum innovation utilizing local teachers in leadership roles. Participants in this program must enroll as partners from the same building and select together one of several "instructional strand topics", each addressing a curriculum innovation or instructional improvement. At an all day conference in February, participants meet their strand leadership team and begin study of the topic. The leadership team convenes their strand again in March and April for full day sessions devoted to continued instruction and formative evaluation regarding classroom implementations by participating teachers of the ideas and activities of the strand. All members of the leadership teams are local instructors, selected by the cross-district administrative team from nominations submitted by each participating district. They are trained as workshop presenters under the auspices of the Oregon Museum of Science and Industry (OMSI) Outreach Program. Three years of evaluation consistently document very high teachers satisfaction with this model of staff development. Districts have begun to depend on the project as a means of introducing large numbers of teachers to the National Council of Teachers of Mathematics (NCTM) standards, the engineering-based "Design Technology' Curriculum from great Britain, the role of language arts in science learning, thematic units of study in elementary education, and coordinated concept development across subject fields in secondary science. By the end of the project, members of the leadership teams feel heavily invested in working for the success of the curriculum changes addressed in their strands. In addition, participants feel encouraged to take risks and implement challenging innovations in their math and science teaching. They respond well to learning from their peers in leadership roles. The teachers perceive themselves as being treated with respect by their districts and often are willing to be model practices for their peers. In those strands where preservice teachers have joined their inservice colleagues, evaluation has revealed high levels of both satisfaction and frustration, understood best in a case by case analysis. Similarly, the pattern of outcomes in strands with a wide variety of grade levels or subject areas represented is complex. Generally, presenters have learned not to defer grade level and subject-centered needs in order to introduce "higher order" principles and practices. The model has succeeded primarily with elementary and middle school teachers. Resistance among secondary teachers to its aims has been noted in their low initial participation and subsequent high withdrawal rate from sections aspiring to communicate a K-12 message.

THE EFFECTS OF HANDS-ON TEACHING STRATEGIES ON PRESERVICE ELEMENTARY TEACHERS' CONCEPTIONS ABOUT EARTH-SUN-MOON RELATIONSHIPS

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The purpose of this study is to examine the effect of three difference hands-on teaching strategies on preservice elementary teachers' conceptions about earth-sun-moon relationships. The teaching strategies are designed to range from concrete to semi-abstract, and from internal to external viewer perspective. Additionally, an attempt will be made to determine if there is an interaction of the variables of spatial ability and logical thinking ability with the teaching strategies. One hundred preservice elementary teachers at a large midwestern university enrolled in an elementary science methods course during the fall of 1990 are the subjects. The researcher is using the course's four laboratory sections as the basis for intact group in which three groups will receive treatment through hands-on instruction. The fourth group is the control, and will not receive hands-on instruction. The subjects will be given pre-test to assess their prior knowledge, spatial ability and reasoning level during the first week of the semester. Five weeks later, the subjects will participate in a month long lunar observation. Following the lunar observation, interviews of randomly selected subjects from each of the four intact groups will be conducted to assess effects of the lunar observations on subjects' explanations of lunar phases. During week twelve of the semester, the three different teaching strategies will be administered a posttest. The final examination for the methods course includes questions which provide opportunity for a post, posttest assessment. This study is currently in progress; therefore, the researcher is in the process of collecting data. However by late winter, data should be processed and analyzed. Some of the questions to be addressed are: (1) What effect does spatial ability have on the subjects' abilities to explain earth-sun-moon relationships? (2) What effect do specific instructional strategies have on targeted concepts? (3) Will reasoning ability affect concept completeness, conceptual change, or conceptual development?

A CASE STUDY OF AN ELEMENTARY SCIENCE PROGRAM

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As an independent research project undertaken to collect preliminary data for a dissertation, sixty three questionnaires were distributed to teachers of science in four elementary schools in a suburban area near Atlanta, Ga. The schools were four of the thirteen in the country school system. Each was chosen for its special students, typical background and location in different types of communities. One is in a primarily white neighborhood with a higher than average family income. Another is in a mostly black neighborhood and is integrated mostly by white students from the rural areas nearby. The third school is the smallest, and is in what was called a "mill village" but where housing is not owned by the mills any longer. Most is now rental property. The neighborhood is mostly poor and partially integrated. The last school is in a rural area with a large number of students who live in mobile home parks, and another segment of "old" established families who have lived in the neighborhood for many years. The researcher teaches chemistry, and is the department head in the local high school. Many years of teaching science at the junior high and high school level has led to the belief that science should be taught early and well. This belief had led to a desire to explore what is being done at the elementary school level and to help in strengthening the program of science at that level. The first step was to determine what is happening now in the county in the science area. The survey was designed and distributed to sixty three teachers of science in the four schools. Forty two surveys were returned. At this time the data is being analyzed. Extensive literacy research has been conducted in designing the survey and gaining knowledge of the needs in elementary science and qualitative research. One question on the survey asked "With 5 being the highest, what is your confidence level in teaching science?" From the results one teacher who rates themselves a "5" and one who rates themselves a "1" will be chosen. These two will be used as the subjects of the case study to explore their background. The knowledge gained from this case study should be most helpful in strengthening the teaching of elementary science.

THE EFFECTS OF A LEAD SCIENCE TEACHER TRAINING PROGRAM ON ELEMENTARY TEACHERS' SCIENCE SELF-EFFICACY

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The purpose of this study is to measure the change in two aspects of science self-efficacy of elementary teachers selected to be trained as Lead Science Teachers (LST's). The two aspects measured are 1) constructs of self-efficacy; and 2) outcome expectancy with regard to science teaching and learning. Using an experimental design, the self-efficacy instrument (STEBI form A) was administered as a pretest - posttest. It was first administered to the experimental and control groups before any prescribed training took place. It was given again after the intensive three week training session for the experimental group and no treatment for the control group. In order to determine the long-term effects of the training, the effects of experience as a Lead Science Teacher, and the effects of continuous intermittent training, a post-posttest will be given to both groups in May. The study includes 63 subjects, 38 elementary Lead Science Teachers in the experimental group and a control group of 25 elementary teachers. The participants in the experimental group were selected from 75 applicants based on a written explanation of why they wanted to be a Lead Science Teacher, two letters of recommendation and a signed commitment from the building principal. The members of the control group all showed an interest in becoming Lead Science Teachers but were not selected as participants in the program. These LST's were selected in March and immediately began the prescribed training program. As part of the program they were assisted by the project staff in completing a science needs assessment of their schools and in the development of Science Improvement Plans to meet the needs for their individual elementary schools. During July, they met for three weeks of intensive training. This training was based on the needs cited in the Assessments and the Science Improvement Plans. Included in the training was instruction and practice in conducting science inservice sessions for other teachers.

THE EFFECT OF AN NSF SUMMER INSTITUTE ON MIDDLE SCHOOL SCIENCE TEACHERS' PERCEPTION OF THEIR LEVEL OF SCIENCE KNOWLEDGE AND KNOWLEDGE AND USE OF VARIOUS TEACHING STRATEGIES AND TECHNIQUES

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This paper presents the results of a study designed to determine whether a 3 week summer Institute for middle school science teachers had an influence on the participating teachers perception of their level of knowledge of science contact and perception of their ability to use various teaching strategies and techniques in the classroom. Eighty-four middle school science teachers were enrolled in one of the three week summer Institutes with 28 teachers each at an east-coast university, a mid-west university, and a west-coast university. The focus of each Institute was to enable teachers to better utilize teaching strategies and techniques such as cooperative learning, learning cycles, conceptual change/pre-conceptions, science process skills, effective questioning and wait-time, all in the context of hands-on science activities. This study sought to identify the perception of the level of teachers' science knowledge and use of various teaching strategies and techniques prior to and immediately after attending an intensive summer institute. At the beginning and at the end of the Institute, teachers were administered two pre-surveys and two post-surveys. The surveys were developed specifically for this investigation and were designed to measure important outcomes of the Institute. The survey Perception of Level of Science Knowledge (PLSK) was the instrument designed to measure the level of knowledge of science content perceived by each of the participating teachers. The survey Perception of Teaching Strategies and Techniques (PTST) was the instrument designed to measure knowledge of and use of teaching strategies and techniques. Simple product moment correlations between pre- and post- surveys were moderate (r =0.42-0.58). The mean differences of these surveys were analyzed by using the means of correlated t-test procedures. Results showed that the teachers perception of their level of science knowledge and their perception of their knowledge and ability to use various teaching techniques and strategies had increased significantly at all three sites. Teachers were also asked to complete a narrative evaluation critiquing the various components of the Institute. Both the quantitative results and the qualitative statements provides evidence that the Institutes were successful in enabling middle school science teachers to acquire both content knowledge and effective teaching strategies and techniques.

INCREASING LEARNING USING QUESTIONS EMBEDDED IN SCIENCE VIDEOTAPES

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Cognitively engaging students in school activities seems to be an important aspect of teaching. One technique which may alter students' attention so that they become more cognitively engaged is that of adjunct questions. Adjunct questions have been empirically studied primarily through embedding them in textual materials. Typically, students read a segment of text followed by a question related to the text. After answering the question the students read a subsequent text presumably while paying close attention to a particular kind of information or a particular kind of processing style which is suggested by the previously answered questions. For example, if a series of questions following test segments repeatedly ask for formulas, students tend to focus attention on formulas presented in later segments of the same text. Such learning effects of questions influence the kind of information focused on (examples: formulas, chemicals) or processing style employed (examples: verbatim, conceptual) by readers. However, the effects of adjunct questions may be effective in conjunction with media other than test. One medium which adjunct questions can be readily incorporated into is videotape. In this series of experiments, two sets of low- and high-level questions will be developed for each of three videotapes, For each level of questions (i.e., low- or high-level) one set will appear as both adjunct questions and achievement test items and the second set will appear as achievement test items only. The reliability and validity of both the adjunct questions and the achievement test will be assessed. Finally, the differential learning effects of embedded post-questions will be assessed by examining students' posttest performance.

TEACHING STRATEGIES UTILIZED AFTER PARTICIPATING IN AN INSERVICE ELEMENTARY SCIENCE PROGRAM

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The purpose of this study was to determine the frequency that elementary teachers taught science over a four week period and what teaching strategies they utilized during that time frame. Twenty-one K-6 teachers of science who had participated in the K-6 Science and Math (KSAM) Project, and NSF sponsored program, during the winter semester 1989 were involved in the study. During January - March, 1990, teachers submitted weekly logs of the frequency and teaching strategies utilized for each lesson. Results revealed that 61.5% of the teachers taught science 16 or more times over the four weeks, and discussion and hands-on were the most frequent teaching strategies utilized.

CREATING QUESTIONS IN SECONDARY SCIENCE EDUCATION

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This research addresses issues of how preservice secondary science teachers begin to acknowledge their own conceptions of science knowledge, and their beliefs about the nature of science learning and teaching. The research questions posed for this project are (1) How do preservice teachers describe the creation of a teaching situation in which they are asked to analyze their own and others scientific knowledge? (2) To what degree are they sensitive to how changes in their conception of a scientific principle influences the direction of their teaching, both in content and method? (3) How do self-reporting and "exit" interviews help inform science educators as to the concepts and principles about science and science teaching that are already held by preservice teachers when they enter their education programs? (4) How can that knowledge help in educators' development of meaningful science education experiences? Science education students are asked to discuss and reflect on their experiences during this semester. They report in their journals the processes of identifying a science teaching event and the science concepts relevant to that event. They construct a clinical interview in order to question and come to understand another student's prior concepts. Transcription and interpretation of their role as questioners allows them to realize their own conceptions of science phenomena, and how that knowledge influences the direction and type of questions they ask. As a result of that experience, which also includes interpretation and analysis of the interviewee's science knowledge, the preservice students develop two different teaching model for conceptual change. These presentations are critiqued by their peers and the instructor. The students are asked to reflect on conceptions of science knowledge, and their feelings about the nature of science learning and teaching at all stages of these activities. The resulting journals and essays indicating the extent of change of meaning as evidenced by their own work, requires the students to be alert to their thinking, feeling and acting. These documents, as well as follow up interviews during the teaching semester are the records of this research. Categories of student thinking, feeling and acting will be identified from the responses. Using concept analysis for further identification of significant regularities, interpretations of the data will be made relative to the research questions. Careful scrutiny of documents will permit individual reactions that are insightful and critical to the study to be retained. This research is in progress, but early interpretation reveals that this process allows students to realize the importance and difficulty of question construction. While uncomfortable with evidence of their own limited knowledge in some areas, they are encouraged by their ability to reframe and reconstruct concepts so that they have new meanings of those areas. The results, as interpreted by the students and instructor, hopefully, will address the gap between content and pedagogical knowledge.

KNOWLEDGE STRUCTURES OF PRESERVICE TEACHERS REGARDING BOTH CONCEPTS OF HEAT AND TEMPERATURE AND PEDAGOGICAL CONTENT KNOWLEDGE OF HEAT AND TEMPERATURE

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The research presented in this pilot study is a description of the knowledge structures of preservice elementary school teachers regarding the concepts of heat and temperature. Also included is a description of the pedagogical content knowledge (PCK) (Shulman, 1987) of the preservice teachers regarding the concepts of heat and temperature. A three part interview, designed to establish teachers' concept of heat, temperature, the differences between the two, the understanding of a hear curve, and PCK (Krajcik and Layman, 1987) was used to establish preservice teachers' concepts. Interviews with each of four subjects, enrolled in a science course for preservice elementary school teachers, were transcribed. Concept maps were created for two parts of the interview regarding heat and temperature. Based on the concept maps and the interviews it was found that the differentiation and integrative reconciliation (Novak, 1984) of the concepts heat and temperature was minimal. Subjects were not able to identify any differences between the two concepts although they were able to give many examples of the concept temperature. The third part of the interview asked subjects to describe the parts of a heating curve. Each of the subjects was able to describe the part of the heating curve. They were also able to describe what processes might have created the curve. It was also found that the preservice teachers, including two who had already completed a science methods course, had poorly developed ideas regarding the teaching methods suitable to elementary school students regarding these concepts. In other words they lacked the appropriate PCK. The subjects were able to discuss activities regarding temperature, i.e., measuring various temperatures around the classroom, but were unable to discuss activities to assist elementary students in understanding temperature or any relationship between heat and temperature. Although the subjects presented an understanding of the heating curve they were unable to describe appropriate activities which would be used to teach the heating curve. In this case subjects were unable to describe appropriate activities regardless of their understanding of the structure of the content. This pilot study emphasizes the lack of content knowledge of heat and temperature and the appropriate PCK of preservice elementary education students. Further research will apply microcomputer-based laboratory activities regarding heat and temperature in an attempt to improve the conceptual structures of preservice teachers as well as their available PCK structures.

A COMPARISON OF LESSON PLANNING DECISION PATTERNS OF NOVICE AND EXPERIENCED BIOLOGY TEACHERS

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This study investigated the decision patterns used by novice and experienced biology teachers in planning a series of lessons on characteristics of living things. Characteristics of living things was chosen as the content used in this study because many secondary students have alternate conceptions of these concepts, and as such the teaching of this concept present a challenge to life science teachers. Three novice and three experienced biology teachers participated. Each teacher was given fifteen minutes to review the content in the selected biology text. The teachers were then asked to write three days lesson plans, while thinking aloud about the decisions being made. Immediately following the think aloud interview, the teachers were questioned from a guided recall protocol about their decision pattern. A list of propositions from each teacher's interview was compiled. Proposition lists were constructed and compared. Analysis indicates that novice and experienced teachers differed in their comprehension of the purpose of instruction, interpretation of the text, and representational repertoires. These differences may have led to the different decision patterns exhibited between the two groups. Experienced teachers placed priority on the development of student understanding and interest. In contract, novice teachers placed priority primarily on content volume and pacing, and secondarily on student understanding. Experienced teachers, therefore, transformed subject matter based on student understanding and novice teachers transformed subject matter based on the use of terms and definitions.

PRESERVICE TEACHERS' PERCEPTIONS AND CONCERNS ABOUT CLASSROOM MANAGEMENT AND DISCIPLINE: A QUALITATIVE INVESTIGATION

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The purpose of this investigation was to qualitatively investigate preservice science and math teacher's perceptions and concerns about classroom management and discipline. The sample consisted of 16 preservice teachers enrolled in a microteaching course. Eleven of the subjects were being certified in science and five of the subjects were being certified in mathematics. The subjects reacted to an open ended questionnaire that asked them to define both classroom management and discipline. In addition, the subjects were asked to comment on their concerns in each of these areas. A systematic qualitative analysis of the subjects' responses resulted in four categories for classroom management and two categories for discipline. Categories of classroom management included: pedagogical skills that promote learning, the smooth operation of the class, classroom environment, and the physical environment. Definitions of discipline were grouped as to whether they addressed the class or the individual student. The subjects' concerns in both of these areas were highly variable and not conducive to the same systematic analysis. However, there were some concerns expressed repeatedly by many of the subjects. In the area of management these concerns included: "Keeping students on task", "Controlling problem students", "Planning", "Setting rules", and "Positive student/teacher interaction". In the area of discipline the concerns included: "Fairness and consistency", "Maintaining student engagement", "Maintaining control", and "Student/teacher rapport". Although subjects, as a group, were able to make a distinction between management and discipline, an examination of the individual responses revealed a rather focused view of management with concerns in both categories being discipline oriented. In general, their understanding seems to be a mixture of theoretical knowledge about management and the practical concern of dealing with individual problems as they arise.

STUDENT BACKGROUND AND ACHIEVEMENT IN UNIVERSITY FRESHMAN BIOLOGY COURSES

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The objectives of this study were to determine if assigning comprehensive final examinations could produce greater achievement in biology and to determine characteristics of students in university freshman biology. Information about students characteristics was obtained from a questionnaire administered on the first class day in selected freshman biology (botany, zoology and general biology) sections. Achievement was determined by a biology content examination developed by the researchers from topics common to each freshman biology course department syllabus. The content examination was administered as a pre-test on the first class meeting of each participating section, and as a post-test at the final examination of each section. The effects of comprehensive final examinations were tested using an experimental group/control group design. Five instructors and their classes participated in the study. Each instructor taught two sections of freshman biology (ex: two general biology or two botany or two zoology classes). One class of each instructor was the experimental group and was assigned a comprehensive final examination; the other class of each instructor was the control group and was assigned a non-comprehensive final examination. No significant difference in achievement on the biology content test was found between the experimental (comprehensive final examination) group and the control (non-comprehensive final examination) group, in either the pre-test or post-test. Oneway ANOVA indicated significantly higher average scores ($p \leq 0.01$) on the pre-test and post-test of the biology content test for each of these groups of students: those with a prior freshman biology course at the university; those who had taken high school biology 1; those who had taken high school chemistry; science majors; biology majors; and those who liked science. Significantly higher average scores ($p \leq 0.01$) on the pre-test only were found for each of these groups of students: those who - did not transfer any hours or transferred 19 or more hours to the university; live on campus; took some advanced science in high school other than biology 2, chemistry or physics; had high school physics; had high school physical science; graduated from a high school outside of Texas; took high school biology 2. Again, none of these groups had significantly higher scores on the post-test. Correlation of pre-test and post-test scores ($N = 845$) with number of high school science courses (from 0-6) indicated that the greater the number of high school science courses taken, the higher the pre-test and post-test scores. A general statistical model of the data set has not yet been attempted, so all general conclusion are tentative. Data will be examined further before drawing final conclusions regarding the effects of comprehensive final examinations on students' achievement on biology content test. Data on student characteristics appear to indicate that the amount of science taken in high school, not necessarily the kind of science taken, was an important factor in achievement on the biology content test.

A COMPARISON OF SIX DIFFERENT DIAGNOSTIC PROCEDURES USED TO CHECK RAW QUANTITATIVE DATA FOR OUTLIERS IN A GENERIC SCIENCE EDUCATION STUDY

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This methodological study compares six different diagnostic procedures used to check raw quantitative data sets for outliers in a generic science education study. Outliers are defined as extreme data points with large residuals. It is argued that an outlier check should be performed on all quantitative data analyzed in science education research to "sound a warning" concerning the accuracy of the collected raw data before standard parametric procedures are applied. Five of the diagnostic procedures demonstrated are regression diagnostics: the leverage point, the studentized residual, DFITS, Cooke's Distance, and DFBETA. These values are obtained through the use of Statistical Analysis Software (SAS) by including the influences option in the model step in Proc Reg. Calculation of critical values then is done to identify potential outlier. The other diagnostic procedure demonstrated is a visual inspection of the scatter plot of the raw data to identify suspicious data points. This generic science education study demonstrates the contract of findings obtained through analyzing all the raw data as opposed to removing various combinations of identified potential outliers provided through the application of all sic diagnostic procedures. Cooke's Distance, being the most conservative procedure, is recommended as the preferred diagnostic procedure to highlight suspicious points in science education research.

A STUDY OF THE IMPORTANCE TEACHERS PLACE ON STS ISSUE INVESTIGATION AND ACTION TRAINING INSTRUCTIONAL GOALS

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The purpose of this study was to collect information from science teachers regarding the status of STS issue investigation and action training instruction in the schools. Teacher input was desired regarding the following: (1) teacher perceptions concerning important STS global issues; (2) teacher comprehension of STS instruction goals; (3) possession by teachers of the knowledge and skills needed to assist students in achieving the goals; (4) teacher need for curriculum materials and inservice training related to each of the goals; and, (5) the degree to which instruction focusing on each of the eleven goals is currently being addressed by teachers. Middle school science teachers were the targeted population for this study. A random sample from the targeted group was selected from a midwestern state with strong state goals requiring both environmental and STS goals. A questionnaire was developed for use in this study, and its content was independently validated by a panel of science educators. The questionnaire was distributed and returned by mail in December, 1989. Ninety-four of the sample members returned the questionnaire, and 90 of the instruments were analyzed. The respondents were predominantly male with an average of twenty-three years of experience. Most teachers reported having completed a large number of additional science content courses but on average had not completed a course in science methods since 1986. Data collected in this study indicate that water resources, air quality and atmosphere, and land use are the most important global STS issues identified by this group. A majority (62% - 83%) of the teachers surveyed feel these goals are an important part of every students' education. A surprisingly large percentage (49% - 34%) did not feel they have the knowledge and skills needed to assist students in achieving the STS goals. A majority (65% - 70%) indicated a need for curriculum materials to assist students in achieving all eleven goals. Inservice training was considered important by a majority (60% - 70%) of teachers in order to assist them in preparing students to achieve all STS goals. Seventy nine percent of the teachers surveyed reported spending less than 25% of their time teaching any material related to STS and only a small percentage of the responding teachers indicated they were currently meeting the needs of their students in regard to these eleven STS goals.

USING INTERACTIVE VIDEO (COMPUTER-LASER DISC) TO TEACH EARTH SCIENCE, ASTRONOMY AND BIOLOGY TO HIGH SCHOOL OR UNDERGRADUATE STUDENTS

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Proponents of interactive videodisc programs in education depict videodisc programs as highly visual, motivating, engaging, capable of increasing student mastery, and teaching more content in less time. The research conducted to date generally supports these contentions. In science education, studies have been conducted on the effectiveness and efficiency of concept development and simulation programs designed for individualized learning. Results of the studies have been encouraging, but not overwhelmingly supportive of the effectiveness of interactive video technology. One study (Smith & Lehman, 1988) assert that the instructional design of the programs produce the positive findings, rather than the medium itself. Much more research is needed before the full potential of the technology can be realized. Critical information must be obtained on how learners with varying characteristics respond to the medium, how the effectiveness of instructional strategies can be enhanced by the medium, and the extent and structure of learner interactions (Brody, 1984). This paper, plus demonstration, will focus on the techniques employed in using this technology to teach Earth Science, Astronomy and Biology to undergraduate students, during the past two years in the Faculty of Education at the University of Victoria. The latest research findings will also be presented and discussed.

AN EVALUATION OF ENLIST MICROS III: TEACHER CENTERS FOR IMPROVING THE USE OF MICROCOMPUTERS IN SCIENCE INSTRUCTION

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The Biological Sciences Curriculum Study (BSCS), with support from the National Science Foundation (NSF), is conducting the third phase of *ENLIST Micros*, *Phase I* developed a set of multimedia materials (text, instructor's guide, videotape program, and computer software) that present the knowledge and skills that science teachers need to use microcomputers in science teaching. *Phase II* developed a model (leaders and building teams attending workshops and seminars and supporting each other) for implementing microcomputers in science teaching. *Phase III*, a 42-month project that began February 1989, builds on the first two phases to achieve the following major goals: (1) Help teachers (K-12) improve their use of microcomputers in science teaching; (2) Test three models for establishing a teacher enhancement project at sites throughout the nation; (3) Determine the ability of regional sites to sustain a teacher enhancement project while phasing out external support; (4) Disseminate information about how to establish successful, self-sustaining teacher centers for improving science teaching. BSCS has found the *ENLIST Micros* project to be effective with teachers in the Pikes Peak region of Colorado, which is continuing into its sixth year; the fourth year and beyond have been supported entirely by the local school districts. During 1989-91, BSCS established ten new teacher center for *ENLIST Micros*. BSCS provided staff from each of these centers with a two-week summer institute, two follow-up leadership seminars, two site visits, and consultative support via telephone and computer bulletin board. BSCS staff, with the assistance of staff at each of the center, is gathering information to evaluate the effectiveness of the trainer-to-trainers approach to replicating the *ENLIST Micros* project at regional sites. BSCS is using the results of the first two years to refine and improve the trainer-of-trainers project for the last year of the project, during which four or more additional regional teacher centers will establish *ENLIST Micros* projects.

THE EFFECTIVENESS OF A RURAL MODEL FOR IMPLEMENTING MICROCOMPUTERS IN SCIENCE TEACHING

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The objective of this study is to research the factors that influence microcomputer usage in rural science teaching. Kansas State University was selected as one of five regional training centers in the NSF-supported ENLIST Micros project, which was developed by BSCS. ENLIST Micros is a 3-year project to help teachers implement microcomputers in school science. It consists of a curriculum preparing science teachers to use microcomputers and an implementation model. Each regional center was selected by BSCS to assess implementation of the model in different geographical and socioeconomical parts of the nation. As the regional center in Kansas, the emphasis was on implementing ENLIST Micros in rural school districts. The research design for this study was developed to reflect the unique and diverse strengths and weaknesses of education in rural communities. Quantitative, as well as qualitative, measures were used to collect data. Surveys, interviews, site visitations, analysis of action plans, and numerous demographic information were collected on each participant. The relationship between the variables was analyzed within site to provide a richer understanding of the factors and across site to increase generalizability. Fourteen teachers from six school districts participated in the project. The teachers were trained in effective science teaching methodology, how to use microcomputers in science teaching, and to evaluate and select appropriate software. At the beginning of the project, personal action plans were written in which the participants defined the classroom changes they wished to make during the project year. The results of the study indicated that teaches increased their use of microcomputers in science teaching. In addition, their efficacy, attitude, and enthusiasm toward microcomputers in science teaching increased. Interaction of the factors within all four variable clusters was evident. Of these four variable clusters, organizational and procedural factors exerted the most influence. The most critical factors were pressures and support from school administration, availability of technical assistance, release time to review software, access to people and resources, the match between personal plans of action and personal teaching style and organizational needs, and on-going implementation assistance. Because all school districts involved in the project were rural, there are not strong differences evident among the school at this point. A critical community factor, however, became evident with the project that is directly influencing Kansas State University's implementation of the BSCS model. The distance the teachers had to drive to attend the workshops and seminars at Kansas State University became too much of a burden. This has caused us to drastically modify the BSCS model to more appropriately fit rural sites. Personal and professional factors were not strongly related to successful implementation of microcomputers in science teaching.

COMPUTER ASSISTED TUTORIALS IN HIGH SCHOOL BIOLOGY: DO THEY WORK?

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The purpose of this study was to determine if computer assisted instructional (CAI) tutorials in high school biology differ in effectiveness in terms of student academic achievement when compared with the more traditional lecture/discussion type of instruction. The sample was three general biology classes. Alphabetical class ranking lists were prepared, which were then alternately separated into the treatment group and control group, producing three sets of two groups of students of comparable academic achievement in the subject matter. The control group received the traditional lecture/discussion photosynthesis lesson and the treatment group, the CAI photosynthesis unit. For the genetics lesson, the two groups reversed roles, with the former control group receiving the CAI instruction. Posttest results indicated that there was not significant difference in student achievement between the two instructional methods. Tutorial CAIs appear to be equal to traditional classroom instruction in their effectiveness in teaching new material.

ALLEVIATING COMPUTER ANXIETY AND IMPROVING ATTITUDE TOWARD SCIENCE TEACHING AMONG PRESERVICE ELEMENTARY TEACHERS THROUGH USE OF VIDEODISC INSTRUCTIONAL TECHNOLOGY

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Among the current goals in science education is the call for improving the quality of elementary science instruction and promoting the use of advanced instructional technologies with students (AAAS, 1990). Recent research has indicated that there may be two significant factors that inhibit teachers' willingness to use effective science instruction or employ computer technology. These are attitude toward science teaching (Shrigley, 1990) and computer anxiety (Loyd & Gressard, 1984). This study examines preservice science teachers' attitudes towards science teaching and their computer anxiety in tandem. Also the relationship of each was compared to videodisc usage. Results reported here represent the preliminary data gathering phase of the projected long-term examination to evaluate the effectiveness of using computer interactive laser videodiscs for science instruction or preservice teachers. Specifically, this study - currently in progress - seeks to determine the effect, if any, of interactive videodisc usage on computer anxiety and attitude toward science teaching or preservice elementary teachers. The Computer Attitude Scale (Loyd & Gressard, 1984) and the Modified Science Attitude Survey (Thomson & Shirgley, 1986) were administered consecutively as a pretest to 26 preservice elementary teachers enrolled in an earth science class. Subsequently, each students was required to interact with the laser videodisc to learn and teach an assigned earth science topic. At the completion of these presentations attitude surveys will be readministered as posttest; and individual group differences in pre-, post-scores will be determined statistically.

KNOWLEDGE ACQUISITION USING INTERACTIVE VIDEODISC TECHNOLOGY

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This study focused on the utilization of the interactive videodisc system to observe the effect that existing knowledge has on their subsequent search for further information. It was expected that the selection of and attention to the subconcepts of the concept to review would be reflective of prior conceptual knowledge; that subjects of low prior conceptual level would not have a directed study strategy, but those with higher prior conceptual level would select and attend to particular items for review. Prior conceptual level was determined by a written test. Subjects were also orally asked which subconcepts they found difficult, and which easy. Subjects were first given a lecture on the concept. After a pre-test they used an interactive videodisc system to review. It was found that subjects with low prior conceptual level could possibly be divided into two groups, namely those who made almost no post-review conceptual gain (low-gaining), and those who made a substantial gain (high-gaining). A similar difference was found for those with high prior conceptual level. Thus prior conceptual knowledge was not necessarily an indication of knowledge acquisition, nor of the strategy. The attention to review was measured in terms of the number of review of each subconcept. It was found that the high-gaining low prior conceptual group had the greatest number of reviews per subconcept and spent the greatest amount of time in review. The high-gaining high prior conceptual subgroup, also tended to repeat each subconcept, but did not spend quite as much time. The order in which the subconcepts were selected was made by both the high-gaining low prior conceptual group, and the low-gaining high prior conceptual group. Thus perhaps it is the attention and not the path that is important. Further data included motivation levels, SAT scores, and confidence in the test answers. Results are discussed in terms of the further development of the use of the technology to aid in knowledge acquisition and in the modification of its acquisition, and in terms of 'explanations' of Chi et al., and Gay's prior conceptual knowledge levels.

EXPLORATION OF FACTORS THAT MAY DETERMINE WHAT MISCONCEPTIONS PROSPECTIVE ELEMENTARY TEACHERS AT WAYNE UNIVERSITY HAVE IN SOME CONCEPTS OF PHYSICAL SCIENCE

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This study examined the relationship between the level of physical science misconceptions, which are held by preservice elementary teachers, and other independent variables. The criterion in this study was the subjects achievement score on the Instrument of Misconceptions in Physical Science (IMPS). There were six predictors: (a) number of years of high school science; (b) number of years of high school physics; (c) number of years of 6-12 science; (d) number of college credit hours in science; (e) number of college credit hour in physics; and (f) the cumulative influence of both years of high school physics and college credit hour in physics. There were three attribute variables: achievement on the Group Test of Logical Thinking (GALT), GPA, and SAT. Cognitive development and the educational level of the subjects were used as controls in this study. Subjects (N = 214) were preservice elementary teachers who enrolled as juniors and senior in science education courses in a large midwestern university. All nine available classes participated in the study, and the number of students in these classes ranged from twelve to thirty. Because there were only a relatively small number of males, the use of gender as an independent variable (IV) is unwarranted. The preliminary objective of this study is to identify some of the misconceptions in elementary physical science, as measured by the IMPS, and to assess if years of 6-12 physics or science classes, either singly or in combination, have a significant relationship to these misconceptions. An equally important goal of this study is to determine whether cognitive development of number of college credit hours earned in physics or science classes has significant effects on the misconceptions, and whether these effects occur independently or as a combination of both. The questionnaire is divided into three parts. The first subtest asks the subject for some relevant demographic information about the preservice elementary teacher and about his or her parents. The Hollingshead's one-factor Index of Social Position (ISP) was used to provide the subjects' educational measure. The second subtest is the IMPS, which is composed of 30 items. The test was developed to assess misconceptions in the following six areas: electricity, density, light, heat, gravity, and astronomy. One way ANOVA will be used to test for significance of differences between means of responses of the same item. The third subtest was the GALT, which was used to measure the cognitive level of the respondent and was composed of 12 items. Procedures for standard and hierarchial multiple regression will be used to analyze the data. The educational level of subjects' parents and subject's cognitive level will be used as controls.

OFTEN IN ERROR, RARELY IN DOUBT. ASSESSING THE CERTAINTY FACTOR IN SCIENCE MISCONCEPTIONS

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A *Private Universe*, a film documentary of science misconceptions held by recent Harvard graduates, illustrates the pervasiveness of science misconceptions and, just as dramatically, discloses the earnest conviction with which science misconceptions are held and shared. These strong convictions may help explain the intransigent nature of misconceptions identified in the research. Previous research has not looked for variation in students' adherence to misconceptions and how this variation might influence their willingness to change their conceptions. It seems reasonable to assume that students who entertain some doubt about their conceptions might be more likely to abandon them than those who, while in error, are not in doubt. The purpose of this investigation is to identify preservice teachers misconceptions concerning selected physical science concepts and assess how firmly these misconceptions are held. A second purpose is to evaluate the effect of a physical science course on both student misconceptions and their degree of certainty. This study examines whether students, indicating a high degree of uncertainty or doubt about their misconceptions, are more likely to abandon them compared to students indicating little or no uncertainty about their misconceptions. Results indicate that the preservice teachers hold strong beliefs in their misconceptions. In most cases there was no difference in scores on the confidence scale between those with many misconceptions and those with few or no misconceptions. In some cases those who had the most misconceptions had the highest certainty scores. Students tested before and after a ten week physical science course showed no significant change in the number of overall misconceptions. However, they did indicate increases in level of certainty on concepts they had demonstrated mastery over on the pretest. In a few cases, individuals retained their misconceptions and became more convinced they were correct. This study contributes to a larger body of research concerned with investigating conditions which facilitate conceptual change. If learner willingness to abandon a misconception depends on the surety with which it is initially held, then teachers need to be aware of both the existence of the misconception and how firmly it is held. If learner uncertainty is a precondition of conceptual change, then the results of this research will have implications for instructional model of conceptual change.

CONCEPT MAPPING TO IDENTIFY MISCONCEPTIONS, CREATE COGNITIVE CONFLICT, AND CONCEPTUAL CHANGE

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In this study, concept mapping is used to externalize student conceptual frameworks in an attempt to facilitate a conceptual shift and at the same time provoke an increase in reasoning abilities. A second hypothesis is that students who demonstrate higher reasoning abilities will be more likely to make a conceptual shift as the result of instruction than students who do not possess these reasoning abilities. The study was conducted with one of two eighth grade teams (n = 92) in a suburban middle school. Three intact classes were each randomly assigned to one of three treatments. For the control group, concept mapping was used strictly as an evaluative instrument to visually inspect student conceptual frameworks. In the treatment groups, concept mapping functioned respectively as an organizational/study tool and to assist students with a self-identification of misconceptions held (as demonstrated by faulty propositional linkages). Additional independent variables identified and operationally defined in this study were student reasoning abilities, prior knowledge, and gender/ethnic classification. Student reasoning abilities were assessed prior to and two months' following instruction of the unit on heat and temperature. The instrument administered was Lawson's (1987) revised pencil and paper edition of his Classroom Test of Scientific Reasoning. Students had been instructed in concept mapping strategies at the beginning of the school year. A concept pre-map was required and completed by all students. Following instruction, a multiple choice post-test was administered to all students, consisting of the same thirty items as the pre-test. Students also completed a concept post-map. One-to-one, videotaped interviews were conducted with students from each of the experimental groups. Written transcripts of all interviews were recorded; these transcripts served to identify persistent student misconceptions and to highlight any conceptual change that may have occurred. The results failed to reject the null hypothesis that no significant difference exists between the group means of mapping and multiple choice instruments as a result of instruction centering on students concept maps. Student concept mapping does provide an excellent vehicle for identifying student misconceptions. Concept map sources improved substantially for all groups as a result of instruction, indicating elaboration of conceptual frameworks and a decrease in misconceptions. Concept mapping does not, however, function as a self-reflection device to foster greater conceptual understanding, as it was attempted in the instructional methodology of this study. The results do support the alternative hypothesis that student reasoning ability plays a major role in students' concept acquisition. It would seem from this study that students with higher reasoning abilities are more likely to increase conceptual understanding and discard misconceptions than their peers with lower reasoning abilities, regardless of instructional method used. Reasoning abilities, however, did not significantly improve as a result of instruction aimed at identifying faulty propositional linkages. Unquestionably clear is the need for teachers to assess both prior knowledge and reasoning abilities of their students as an antecedent to instruction, and to embrace strategies that will encourage active accommodation of scientifically valid conceptions.

CONCEPTUALLY INTEGRATED INSTRUCTION IN SCIENCE: AN EXAMPLE

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In the past, numerous theorists and researchers have discussed the importance of the structure and integration of conceptual relationships for student understanding. This idea has, for example, been an integral part of schema theory (e.g., Anderson, 1984), Ausubel's cognitive learning theory (Ausubel, Novak & Hanesien, 1978; Novak & Gowin, 1984) and expert-novice research (e.g., Chi, Feltovich & Glaser, 1981; Chi, Glaser & Rees, 1982; deJohng & Ferguson-Hessler, 1986; Reif & Heller, 1982; Silver, 1975). These studies and others imply that what will be called *conceptually integrated instruction* is effective for student understanding. That is, students would be more likely to construct meaningful and useful understanding of subject matter during instruction in which ideas are intentionally and explicitly related across time (e.g., class, periods) and forms of instruction. An Integration Matrix, based on the concept mapping procedures of Novak & Gowin (1984), was developed to describe the extent and form in which the instruction was *conceptually integrated*. The short term goal of this research is to test the usefulness of the matrix devised for the investigation of the level of integration of the qualitative interrelationships between concepts as they are presented during instruction. This paper presents an example of the matrix and discusses how it might be used to investigate the influence of the interrelatedness between concepts on students' subsequent understanding. Should this prove feasible, the long term goal is to develop criteria and guidelines that can be used to guide teachers in the construction of conceptually integrated instruction.

STUDENT DESCRIPTIONS OF THE NATURE OF SCIENCE

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Descriptions of how students understand the way science proceeds as a growth of knowledge industry are conspicuously few despite volumes of literature creating top-down definitions of the nature of science and its crucial role in teaching students to act like scientists. Yet, this abstract concept permeates science curricula in forms like "The Scientific Method and Discovery Learning". What ideas do students actually have concerning the nature of science? How does their understanding affect students' views of the scientific enterprise and their role in it? This study addresses these questions. A description of student understandings of the nature of science is especially important in light of developments in philosophy and psychology, suggesting that a learner's existing understanding has tremendous influence on further learning. A recognition of the critical role theories play in the perception and construction of knowledge and the description of learners as active interpreters working within cultural contexts to build understandings have been revolutionary in changing the way philosophers, psychologists, and science educators look at science as a way of knowing. Viewpoints influence not only what information is accepted as valid; they also impact the way information is sought and arranged. If theoretical perspectives are determinants of learning as well as learning outcomes, then learners' epistemologies must play significant roles in the adoption of learning strategies as well as the acquisition of science content. This influence is even more pronounced of science content. This influence is even more pronounced in the development of scientific understandings, since science explicitly deals with criteria for evaluation of new information. This study contributes to research on student learning in its exploration of student understandings of the nature of science and the scientific enterprise, rather than of inferred "correct" understanding. Such an exploration provides a coherent view of student understanding of science, a base on which to encourage the construction of more sophisticated and enabling conceptions of the scientific enterprise. These concepts play key roles in the development of attitudes toward science at an important decision-point for students in their school science experience. A clearer understanding of the views students have on scientists and of the scientific process might enable the formulation of strategies to keep students interested in the pursuit of careers in science, particularly females and minorities.

THE REMEDIATION OF MISCONCEPTIONS ON EQUILIBRIUM OF CHEMICAL REACTIONS AMONG HIGH SCHOOL PUPILS

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The purpose of this study was: (1) to ascertain the level and extent of misconceptions on equilibrium of chemical reactions amongst pupils in standard 10 (grade 12); and (2) to investigate and validate a remedial program to rectify and eliminate these misconceptions. The paper briefly relates to viewpoints on misconceptions and to remedial measures to eradicate misconceptions. The universum consisted of four equivalent classes of about 20 pupils each (N = 83) who had completed a course in Chemistry. Two of the classes were used as the control group and two as the experimental group. The pretest consisted of: (1) test and examinations in the Chemistry course; (2) the administration of an adapted and extended questionnaire based on published literature and; (3) interviews. The results of the pretest showed no statistical significant differences between the control and experimental groups and showed several misconceptions regarding amongst others: (1) open and closed systems; (2) the "left hand side of an equation" and the "left hand side of a reaction"; (3) the length of the arrows in equilibrium equations; (4) the mole concept and the concept of concentration; (5) the application of le Chatellier's Principle; (6) microscopic and macroscopic properties of a substance; (7) the theory of collisions. The control groups were exposed to ordinary revision work consisting of discussions and working through examination and test papers. The experimental groups were exposed to a shorter period of similar revision work supplemented by demonstrations and hands on and inquiry oriented experiences related to equilibrium. The posttest consisted of similar tests and examinations, the administration of a similar questionnaire and similar interviews as was the case with the pretest. The posttest showed a statistical significant improvement of the experimental groups in comparison with the control group. It was thus concluded that the particular program consisting of demonstrations and inquiry based hands on experiences could be used with an ordinary revision program to enhance pupils understanding of equilibrium.

STUDENT ABILITIES TO CONSTRUCT AND INTERPRET GRAPHS: CONTRADICTIONS BETWEEN THE RESULTS OF CLINICAL INTERVIEWS AND MULTIPLE-CHOICE INSTRUMENTS

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Research was done to investigate students' abilities to construct and interpret graphs. Seventy-two subjects in 7th, 9th and 11th grades were administered individual interviews and also completed a paper/pencil graphing test. Using the individual interviews enabled examination of possible explanations for graphing difficulties. The possible hierarchical relationship between elements of graphing was also examined. In addition, comparisons were made between the results of the individual interviews and multiple choice instrument as well as compared to the results of other research studies using paper/pencil instruments. The results indicate that this sample of students shares common difficulties found in other studies regarding constructing and interpreting graphs; no apparent hierarchical relationship exists between elements of graphing, especially when comparing results of individual interviews versus multiple choice results; the results obtained through the clinical graphing interviews were very different from similar questions assessed through multiple-choice formate in other research studies, indicating that multiple-choice questions may not be a valid measure of graphing abilities.

USING GOWIN'S VEE INSTRUMENT FOR CLARITY IN SCIENCE FAIR PRESENTATIONS, LAB REPORTS, AND THE READING OF PROFESSIONAL JOURNALS IN SECONDARY SCHOOLS & COMMUNITY COLLEGES

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In many areas of science education, the Vee can be used to enable a student to make the connection between lecture and laboratory, to guide science fair research and make for an easy to understand presentation. It is also valuable for student understanding of professional research journals. Gowin's Vee is divided into elements or concepts relevant to epistemology (events, objects, records of events and transformation of those records, concepts, principles, theories, knowledge claims, and telling focus questions). The theory of educating behind the Vee says that knowledge is an evolving population of concepts and is a product of inquiry in which the relation of concepts-event-record of events is paramount. At high school science fairs, research is represented by a scientific paper and display. A team of 3 judges visits the student's display and leaves for 5 minutes to read through the scientific paper. When the judges return, the students presents his/her research, followed by a questioning and discussion period between the student researcher and the judges. This last for 20 minutes. Many of my students have found that they are more at ease discussing their research through the Vee much in the way they have learned to understand laboratory research in their science classes. The Vee strategy proves to be quiet helpful to the judges as well. Science education research is guided by a theoretical framework. Underlying all research is the researcher's cognitive methodology used in the design, performance, and interpretation of the study. Oftentimes, papers are published in scientific journals which begin with a focus on a particular question, yet end up with results that answer an entirely different question. Why this happens so often may be due to many reasons, but some that become obvious in these papers are: (1) the researcher seems to use different background theory to drive the design of the study than that which (s)he uses to interpret the results; or (2) the researcher may have found some surprising (accidental? unexpected?) results that overshadow the results answering the original question and become so excited that (s)he reported on only those results and neglected to change the focus question at the start of the paper. Although the results may indeed be exciting, the reader is left with no answer to the question the author posed at the outset. The apparent lack of attention to the possible methodological difficulties in existing science research today can be put in better check by using Gowin's Vee to guide the conceptual and methodological aspects of a study. The Vee is a scaffold device that makes clear how knowledge is made as a consequence of the process of inquiry.

ACCIDENTS IN TEXAS HIGH SCHOOL CHEMISTRY LABS

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In a response to the 1985 adoption of the Texas Hazardous Communication Act, laws concerning eye protection, a state requirement of 40% laboratory time and new health and liability concerns, the Science Teachers Association of Texas has established a safety research program. Safety workshops, curriculum materials for safety instruction, and an extensive instructional laboratory safety checklist (West, 1990) have also been provided. As a component of the safety research program, a data base on the accident rate in secondary science laboratories is being established. This pilot survey of Texas chemistry teachers for 1989-90 was the first step in building the data base. From responses on an initial free response form and a review of previous survey instruments, a final questionnaire with Likert type responses was developed. A separate form was provided for descriptions of accidents and related comments. A random, stratified, geographically distributed sample of 200 chemistry teachers was obtained from the Texas Education Agency. Each was sent a questionnaire and description form. One hundred and two surveys and descriptions of 87 accidents were returned. Although the accident rates were not alarming, other indications of safety were of concern such as unsafe class sizes; inadequate room sizes; the number of preparations; lack of required safety training and the relationship with greater accident rates; buildings without MSDS files or teachers who don't know if a file is available; lack of adequate ventilation; lack of acid cabinets, flammable liquid cabinets, and showers; students who do not wear goggles until all cleanup is completed; lack of a school nurse in the building and the lack of accessible phone. An alarming number (65%) of chemistry teachers teach three or more preparations. Three or more preparations for a science teacher is very demanding. The 40% laboratory time requirement, while sound academically, is similar to teaching an additional course because of the large amount of preparation of materials and equipment for implementing the labs. Further, 31% of the chemistry teachers reported teaching courses for which they are not certified and 69% responded that they did not have rooms of adequate square footage (45 square feet per student in the classroom/laboratory or 60 square feet including storage and preparation area) for a class of 24 students. Brennan (1970) revealed that the higher the class enrollment and the smaller the laboratory space, the higher the frequency of accidents. Similarly, Young (1972) reported the higher the enrollment, the higher the frequency of accidents. Thus, there is strong linkage between large class size or inadequate room size and increase in frequency in accidents. Also of great concern is the report from 61% of the responding Texas Chemistry teachers that they did not receive the REQUIRED annual safety training. Most of those teachers were from schools whose enrollment was less than 1000. Are smaller schools neglecting the safety training of personnel? Associated with the concern for safety training is the finding that those chemistry teachers who did not receive the annual safety training had 11% more accidents in 1989-90 than those teachers who received training.

PROJECT SMART (SCIENCE/MATHEMATICS APPLIED RESOURCES FOR TEACHING) "KIDS AT WORK PROGRAM"

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Project SMART (Science/Mathematics Applied Resources for Teaching), affiliated with the Triangle Coalition, is a model program designed to improve elementary science and mathematics instruction by mobilizing community resources available in most small cities and rural areas in the United States. Elementary teachers' needs in the areas of mathematics and science instruction were assessed in 1987 via a county-wide needs assessment, as well as in discussions recorded by a participant observer in Project SMART over the course of the past two years. Project SMART was developed to meet these needs. Four teams of one secondary and two elementary teachers were recruited in May of 1988 to participate in the development of inservice workshops in early July. Twelve elementary workshops were drafted during the summer session. They were offered during the following school year. The new classroom activities are explicitly designed to show how school science and mathematics are used by adults in the workplace. The teachers and industry representatives involved in designing the unit offer staff development workshops for all grade-level teachers in schools within busing distance of the industrial site. Teachers attending a workshop go on the field trip tour and do many of the classroom activities to prepare them to teach the unit. Teachers are then permitted to schedule field trips for their classes and borrow kits which contain the materials needed for a class to do the science and mathematics activities that complement the trip. We collected extensive data on the effects of the project on the perspectives of the participants involved. Participant observation revealed that the sessions were characterized by active discussions and participation. Teachers raised a variety of questions about the practical implications of the workshops, the content, classroom management, and theoretical issues relating to inquiry teaching. Concerns identified by participant observation indicated some teachers wanted more information on how to integrate activities presented into cohesive units of instruction. Project SMART is a cooperative community endeavor. The model we have developed is one that could be implemented by any school district or teacher center in the state to identify elementary science and mathematics advocates in the schools who can assess the needs of their colleagues, use the advocates' contacts in local businesses and universities to build an effective science and mathematics resource group, and utilize the talent of the resource group to support the advocates within the schools to meet the science and mathematics needs of their colleagues and students.

ENHANCING THE SCIENCE CLASSROOM ENVIRONMENT FOR CULTURALLY DIVERSE STUDENTS: THE OMAHA PUBLIC SCHOOL EXPERIENCE

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This poster session describes the qualitative study which seeks to document the process of change in the ability of science teachers to teach nontraditional students more effectively. During summer 1989 and 1990, a total of 33 science teachers and administrators from the Omaha Public Schools met for four weeks to explore strategies for improving science teaching for minority and women students. The workshop brought together three powerful themes: (1) understanding the strengths and needs of minority students; (2) cooperative learning; (3) content selection based on solving problems that are important to students. Workshop participants developed new instructional units using these themes, to enhance the classroom environment for culturally diverse students. At this session, data from participants journals, structured observations in classrooms, analysis of class and workshop videotapes, interviews with teachers and supervisors, and student surveys will be presented to illustrate the change process. Samples of lessons, videotapes of classes and workshop sessions, and a plethora of stories will be used to convey the substance and spirit of changes in teacher/students classroom interactions.

EFFECTS OF SCIENCE LEADERSHIP INVOLVEMENT IN THE CLASSROOM ON SCIENCE ATTITUDES OF NATIVE AMERICAN ELEMENTARY SCHOOL STUDENTS

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Today our national government has confronted educators with the indisputable challenge of improving science education for minorities. Within the United States, the American Indian population is among the least represented minority group in the field of science. National norms in mathematics and science as well as science related careers, indicated an alarming deficit in the numbers of American Indians represented. The Bureau of Indian Affairs, as well as other federal offices, have recognized the educational plight of the American Indian; and in July 1990 the U.S. Department of Education established the Indian Nations at Risk Task Force for the purpose of studying existing conditions and determining directions for future improvement. It is crucial that educational research refocus traditional avenues of inquiry to include examination of educational strategies which improve learning among the Native Americans. The proposed poster session will report research related to the Indian Nations at Rick Task Force's goals which suggest ways to improve science and mathematics proficiency and to train high quality school personnel. The research in progress examines the following hypothesis, which is suggested by "effective schools" literature: students who attend school where the principal plays an active instructional leadership role will achieve at a higher level and have a more positive attitude toward school subjects than will students attending schools without principals taking and active leadership role. Using a pretest - posttest design in twenty BIA schools in five states, this study will examine the effect of one independent variable, principal's leadership role, with two levels, "active" or "passive", on the dependent variable, student attitude toward science, as measured by the "Science Attitude Inventory" developed by Matthews (1990). During the treatment period, the 1990 fall semester, fourth through sixth grade Native American students will be taught science in schools where the principal takes either an "active" or "passive" role. In the "active" schools, principals: (1) Engaged in observation and/or direct participation in science activities with students on a weekly basis for a minimum of thirty minutes in at least two classrooms in grades four through seven.; (2) Hold a weekly meeting with the school's teachers to plan science instruction.; (3) Provide continuous staff support toward a shared vision of science education. In the "passive" schools the principals will not perform these activities. However, in all schools at least one teacher has attended a two week BIA Principals for the Advancement of Leadership in Science (PALS) training session on science school improvement. Potentially effective science instructional materials will be available to the staff in all schools, but the principals will be playing differing roles in two groups. To determine the principals' fidelity to their designated "active" or "passive" roles, school visits will be conducted prior to the administration of the posttest.

SEX DIFFERENCES IN THE CHOICE OF UNDERGRADUATE SCIENTIFIC PROGRAMS OF STUDY

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The paucity of women choosing careers in science, mathematics, and other technical fields concerns scientists and science educators. The proposed research relies on existing literature to formulate a conceptual (path) model to explain gender differences in the choice of physical vs. biological science college majors. The path-analytic model will be tested using the nationally, representative High School and Beyond data base via a series of ordinary least squares (OLS) multiple regression equations. Further, a review of relevant philosophical literature will serve as a framework for interpreting the results of this empirical inquiry. Incorporating important philosophical thought moves beyond the existing literature, allowing this study to shed new light on the gender gap in undergraduate science majors and the methodology used to address this question.

THE PLANNING PRACTICES OF BIOLOGY TEACHERS IN DESIGNING TESTS AND OTHER ASSESSMENT PROCEDURES

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The purpose of this study was to gain a better understanding of the planning processes used by high school biology teachers in constructing tests and other evaluative procedures. The study investigated the influence of various factors on the decisions teachers made about what to evaluate and how to assess student achievement. These factors included (1) teachers' epistemological beliefs about the nature of science knowledge, (2) their beliefs about desirable and undesirable testing practices, (3) their training and experience in constructing various kinds of tests and alternative modes of assessment, and (4) the testing practices they experienced when they were students. The effect of the teachers' planning practices on the validity of the assessment procedures they created and the inferences they made based upon measurements obtained from these procedures is explored.

CHARACTERISTICS OF TESTS AND OTHER PROCEDURES USED BY BIOLOGY TEACHERS

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The purpose of this study was to determine the extent to which teacher-made-tests and other measures of pupil learning were congruent with the teachers' instructional goals and their beliefs about science curriculum and instruction. Because test scores were used as a major indicator of students' science learning, it was important to assess the quality of items used in the tests. All measures used by 15 high school biology teachers during the first quarter of the school year were collected and analyzed. Teachers' beliefs were determined from notes taken in intensive structured interviews.

ASSESSING ATTITUDE TOWARD TEACHING SCIENCE WITH QUALITATIVE AND QUANTITATIVE METHODOLOGIES

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Various researchers have advocated the value of combining quantitative and qualitative methodologies in educational research. The purpose of this study was to assess the attitudes of preservice elementary teachers toward science teaching using two data collecting procedures. Attitude data were derived from: 1) A Likert-scale attitude survey representing the quantitative tradition, and 2) A standardized interview representing the qualitative tradition. The data collected from each procedure were analyzed and combined into the overall attitude assessment. In addition, comparisons were drawn as to the interpretive insights gained from each methodology. Five female preservice elementary teachers who had completed the elementary science methods course were given a 30 item Likert-scale instrument which assessed attitudes toward teaching science. The subjects were also interviewed while completing the attitude survey to provide verbal reasons and justifications for the response to each item. Data analysis involved comparing the attitude survey scores with the instrument developer's data and identifying key words and themes from the interviews. It was found that four of the five subjects had similar scores, all positive in attitude toward teaching science. However, the interview data revealed that: 1. Diverse origins of a positive attitude toward teaching science existed among the subjects. 2. Identical responses to the same item were supported by different beliefs and interpretations of the topic. 3. A conservative response pattern was acknowledged bv the lowest scoring subject near the completion of the attitude survey suggesting less attitude difference than the score indicated. Combining qualitative and quantitative research methodologies provided a perspective and sensitivity that would not be available with one methodology alone. Whereas the scores from the attitude survey yielded a benchmark of relative attitude strength, the interview data revealed insights into the origins and justifications for the expressed attitude. Thus, examination of the interview data aided greatly in the interpretation and explanation of the survey scores.

THE DEVELOPMENT OF AN INFORMATION LINK BETWEEN AN ESTABLISHED NETWORK OF INDIVIDUALS WORKING WITH SUSTAINABLE DEVELOPMENT AND SECONDARY EDUCATORS

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Secondary school students in the United States have little understanding of the concept of sustainable development. Instead, students focus on separate subjects as discrete compartments, rarely applying the information from one subject area to another. Since sustainable development encompasses many disciplines, the concept is rarely understood. The focus of this program is the multidisciplinary nature of sustainable development, and the transfer of this concept to secondary school teachers through conservation education. The specific goals of this program include: 1) The organization of a network of conservation biologists which is willing to provide a resource for secondary educators. 2) The development of practical resource materials for secondary school educators which address and include the multidisciplinary aspect of conservation education. 3) The establishment of a base for teaching conservation education and the concept of sustainable development at the Florida Institute of Technology. The global lack of understanding regarding the concept of sustainable development stems from the fact that a multidisciplinary approach of examining issues is not taught in secondary school classrooms. A vacuum exists in conservation education because the concept of sustainable development is not taught. The discrete nature of secondary education and the lack of materials do not lend themselves to presentations of the concept of sustainable development in the classroom. Individuals in these organizations will be participating in the development of a program which provides an information link between the network and secondary educators. This network includes, but is not limited to the following organizations: Organization for Tropical Studies, USAID, World Bank, North American Association for Environmental Educators, World Wildlife Fund, and the Latin American Division of Nature Conservancy. One approach to bridging the information link is to develop practical resource materials for secondary school educators to increase student understanding of the multidisciplinary nature of sustainable development. These resource materials include an information packet for secondary educators which includes biological concepts as well as political, social, and economic concepts. In addition, a protocol and outline for seminars and workshops to be used by conservation organizations in their dealings with secondary school programs will be available. These resource materials will be incorporated into the conservation education courses offered at the Florida Institute of Technology, including the Biology, Oceanography and ocean Engineering, and Science Education departments. In order to facilitate the comprehension of the concept of sustainable development, the multidisciplinary approach of examining issues will be used in the courses. In addition, the Science Education courses will include student training in the most effective techniques for a multidisciplinary approach to teaching.

THE CHANGING ROLE OF ENVIRONMENTAL EDUCATION

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The historic development of environmental education was examined through an analysis of the changing attitudes towards the American wilderness. The early European settlers brought the Old World fear of the wilderness to the western world. This aversion towards anything untamed persisted until the romantic movement which altered the societal perception of nature. As the urbanization of the United States became reality, so did the apparent appreciation of land which was left untouched. Over the past century, the evolution of environmental education has shown a need for such an emphasis through the areas of conservation education, camping education, and outdoor education. As this research continues, historic literature suggests that the origin of current environmental education was greatly different from environmental education of today.

MEANINGFUL AND ROTE LEARNERS' MENTAL MODELS OF MEIOSIS AND SELECTED GENETICS CONCEPTS

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A valued outcome of science education is for students to formulate sound conceptual frameworks about the world and how it works. An area of concern in biology is the meaningful understanding of meiosis and the relationship of meiosis with genetics, particularly the use of the Punnett square (Cho, Kahle, & Nordland, 1985). Students that learn meaningfully are said to formulate and retain sound mental frameworks (Bodolus, 1986; Cliburn, 1988; Pankratius, 1987). Conversely, rote learners formulate weak cognitive frameworks or none at all, and retention of material is meager. But, what is the nature of the mental understandings they do formulate and how are they different? Furthermore, since there is little benefit to students' understanding when rote learning of concepts is used, why does this technique seem to prevail? Research by Ames and Archer (1988) indicates that students may have strong orientations toward performance (achieving high grades), and this is related with the type of learning strategies they adopt. Is the type of mental framework students construct related with a desire to be successful performers? This study uses mental modeling (Mosenthal & Na, 1980; Mosenthal, in press) as a method for describing students' knowledge structures of meiosis and concepts involved in the use of the Punnett square in biology. The purpose of this study is to determine relationships between mental models of students that tend to learn meaningfully and those that tend to learn by rote, given either one or two forms of instruction (treatments). Subjects for this study were tenth grade biology students (N=118). Students were given a 65-item Likert instrument to provide a measure of students' orientation toward performance (achieving high grades) and toward learning (learning for the sake of learning) (Ames & Archer, 1988; Dweck, 1986). Sub-samples of students who learn science meaningfully and those who learn by rote were identified using the Learning Approach Questionnaire (LAQ) (Donn, 1989; Entwistle & Ransde, 1983) and teacher ratings of how their students learn. Students were categorized as rote or meaningful learners based on a composite of the individual's score on the LAQ and teacher rating. Meaningful and rote learners were randomly assigned to one of two auto-tutorial instructional treatments. The students were given a pre-test and a retention test using the mental model technique describe by Mosenthal and Na (1980) and Mosenthal (in press.). Student mental models were analyzed using a parsing method (Mosenthal, in press). The results of students' mental models were coded and quantitatively analyzed by learner (meaningful or rote) and by treatment. Finally, an analysis was conducted to determine the relationship of achievement goal orientation (performance or learning) with the type of mental model students construct.

THE EFFECT OF EXTERNAL VERBALIZATION BY FIFTH GRADERS ON THE DEVELOPMENT OF LEVER CONCEPTS

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While all learning is verbal in nature, because words are the symbol in which humans speak and think, the format in which the verbalization is done may affect the success of the transfer of works into meaningful conceptual constructs. The purpose of this study was to isolate and examine the influence of external verbalization on the development and understanding of lever concepts. An achievement test and three lessons targeting lever concepts were developed, piloted, and revised. The study was implemented and completed in Spring of 1990. The design for this study was quasi-experimental using a pretest and post-test with a control and two treatment groups. All three groups received classroom instruction in levers. The only difference in instruction was in the amount and target of required verbalization. For the control group, no external verbalization was required, but any normally occurring verbalization was not prohibited. Both treatment groups were required to verbalize externally, both observations and concepts about levers. For one of the treatment groups the target of verbalization was the teacher. For the other treatment group the required verbalization was directed to a peer partner. The subjects for the study were 269 fifth grade students from four schools in a North Carolina School System. The subjects were students enrolled in twelve classes, three classes from each of four schools. Utilizing a complete random block design, each of the three treatments utilized in this study was applied to one class at each school. Analysis of the data (ANOVA) indicated no overall difference on post-test scores or on high order and low order questions of the test. Further analysis of scores based on ability level as measured by the CATM and CATR indicated that external verbalization with teacher as target is beneficial to students with low verbal ability (score in lowest quartile). It was further indicated that ability in math (as indicated by the CATM) may also influence development of lever concepts, even though the amount of mathematical skills involved are very low level. Recommendations for continuing research include: repeating experiment using different concepts, using other grade levels to measure the developmental aspect of need to verbalize externally, keeping records of the types of verbalizations that go on in peer groups, and controlling the selection of peer partners to look at interaction of ability levels when using external verbalization.

LEARNING SCIENCE THROUGH READING AND WRITING

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Dave: How do you use the study guide? Jacque: I thing the study guide is a great idea because by doing that, that helps you because... you read it, and you sometimes say it, and you hear it, and you write it. So there's like four thing that help you remember.
Student Interview (May 1988)

Jacque is a ninth grade biology student in Joe Ruhl's biology classroom. She is describing to Dave how she uses a resource Joe publishes for his students. Jacque is a member of one of several small groups who work together on several different types of biology activities. Students are involved in finding, sharing, discussing, and writing their assigned work. They make steady progress toward shared goals. This and similar views of classroom life are seldom seen by science education reformers. When national reform measures are mandated, curriculum models and new methods are imposed on existing structures. This top down reform method is destructive and self-defeating. As a result, those most directly involved (teachers and students) are disempowered and disenfranchised. This study describes how students learn biology in Joe Ruhl's classroom. It has implication for those who are involved in grassroots transformations of science education programs that involve reading and writing to learn.

ANALYSIS OF ANALOGIES USED BY SCIENCE TEACHERS

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The purpose of this study is to examine the use of analogies by science teachers. The data is based on 40 transcribed observations of 20 teachers belonging to 13 school districts. The variety of similarities used in junior-high classrooms will be analyzed according to Gentner's structure mapping theory, then analogies will be studied according to the rules of rigor outlined by Gentner and Jeziorski. Among other things, these rules include: structural consistency, preservation of relations, and use of the systematic principle. The study then will take a critical look at the findings and their implications for practice.

TRADITIONAL PRE-POST ATTITUDE MEASUREMENT VERSUS A POST ONLY ATTITUDE SELF-ASSESSMENT IN AN ELEMENTARY SCIENCE METHODS COURSE

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Science attitude scales are routinely used to attempt an estimate of how attitudes change as a result of an educational experience. Quasi-experimental procedures stipulate that student's attitude be assessed just before the experience and again immediately after. Any resulting change in attitude is typically taken to be a result of the educational experience. This study utilized 72 undergraduate elementary education majors enrolled in a science methods course. During the first class, all students completed a ten-item Likert-type science attitude instrument. This instrument was constructed to reflect the affective course objectives. At the conclusion of the ten-week course, students again completed the instrument. This post-instrument asked students to recall how they felt at the beginning of the course as well as the end. This sampling resulted in data that gave students' initial attitude, their recollections of their initial attitude, and their final attitude. Analysis of the data indicated that the students showed a slight positive attitude shift when the traditional pre-post scores were examined (average < 1/2 Likert unit). A significantly larger difference was evident when the final attitude scores were compared with the recollection of initial feelings. This data indicated an average difference of 1 Likert unit. The appropriateness, usefulness, and possible ramifications of this method of attitude assessment are discussed.

THE USE OF PANTOMIME TO ENHANCE ELEMENTARY SCHOOL STUDENTS' UNDERSTANDING OF SELECTED ABSTRACT SCIENCE CONCEPTS

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The purpose of this study is to investigate the use of creative drama as a supplemental teaching technique in the elementary science classroom. The specific research question asks if the use of pantomime, in a hands-on unit about solar energy, enhances elementary students' conceptual understanding about light, heat, and energy. The students pantomime or act out a phenomenon that is being studied. For example, if the students are studying light and heat, several students might be molecules on the surface of an object and another student might be a photon. The students would then pantomime the interaction between the photon and the molecules. Other examples might include students becoming molecules of air that are slowly heated up, blood cells bringing oxygen to muscle cells, and a wave moving through a body of water. This research consists of an ethnographic pilot study (completed December, 1989) and an experimental study currently in progress. The pilot study involved one teacher and her fifth grade science class. She participated in an extensive inservice training program which included pantomime as an instructional strategy. After the completion of the inservice program conducted at The University of Texas, she was observed using pantomime in her classroom. Data were collected during a number of classroom observation sessions and interviews of the students and the teacher. The experimental study is currently in progress. Two teams of teachers are being trained to teach a hands-on unit about solar energy. One team will serve as the control and will not be instructed in the use of pantomime. The experimental group will be shown how to use pantomime with their students and will be asked to use it while teaching the unit. Data will be collected with an objective test assessing the children's understanding of concepts relating to heat, light and energy. In addition, qualitative data will be gathered using interviews and writing assignments. The results from the pilot study are very encouraging. Most of the students rated pantomime very high when asked to list what activities they learned the most from. Almost all of the students reported that they enjoyed that part of class and were very attentive. The teacher saw it as both a powerful teaching tool and assessment instrument. She reported a number of times when it helped her see some of the students' misconceptions and used the pantomime to help students think about the concept in a new way. Another interesting outcome was the teacher's progression to a more contemporary view of the nature of science. She admitted that at the completion of the inservice program she didn't really understand what was meant by a scientific model. After using creative drama with her students she decided that the pantomime is a model. She began to see that her role as a teacher is to help students construct models of the phenomena being studied. The experimental study is in progress and preliminary results will be available for the poster session.

SCIENCE ACHIEVEMENT IN RURAL SCHOOLS: DATA FROM HIGH SCHOOL AND BEYOND

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Research seems to indicate that rural school students may not be contributing to the decline in science achievement to the same extent as urban and suburban students. The arguments supporting rural science education generally take one of two forms: One is that rural students have greater experience with natural or agricultural environments which provide them with experiential knowledge of science and their teachers with concrete examples from which to teach science concepts; the other is the smaller class sizes and the nature of rural communities foster the development of stronger interpersonal relationships among students and teachers which leads to higher achievement. The major purpose of this research is to examine the effects of school size and school context (rural, suburban, or urban) on high school science achievement for students. A conceptual model will be tested using High Schools and Beyond (HSB), a nationally representative longitudinal data base. With these data, we expect not only to describe the differences in science achievement among rural, suburban, and urban students, but to suggest factors that contribute to these differences.

THE RELATIONSHIP OF SCIENCE EQUIPMENT USAGE TO THE ATTITUDES AND ACHIEVEMENT OF SEVENTH-GRADE STUDENTS

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Regardless of how a science program is to be organized, the success of the program is dependent mainly on the teacher. The teacher's attitude toward science can be influential to the students' attitude toward science (Blough and Swartz, 1984). One of the primary reasons to teach science by inquiry was to develop positive attitudes of the students (Esler and Esler, 1989). Even though it may require a long time to encourage students to develop a positive attitude toward science, these positive attitudes will emerge when students feel successful (Xeitherand Barufaldi, 1988). These successful experiences can occur when pupils are allowed the opportunity to explore and discover on their own. Henceforth, if science equipment is provided, will the attitudes, as well as the achievement scores, increase? The purpose of this study is to determine the relationship of science equipment usage to attitudes and achievement of seventh grade students in six parish schools in Louisiana. The State Department of Education in Baton Rogue, Louisiana, and the Department of Natural Resources have piloted a project of selected seventh grade classes to receive equipment, materials, curriculum guides, and manuals for three academic years. The project is funded 60 percent by the Louisiana Department of Education and the Dwight D. Eisenhower Act of 1989, and 40 percent of the guides and 100 percent for the Text/Lab manuals by the Louisiana Department of Natural Resources through the Petroleum Violation Escrow funds as approved by the U.S. Department of Energy. These chosen teachers are provided needed materials and equipment to conduct activities in the seventh grade classroom of the parish schools. The Energy Education project is a three year funded project. The sample to be used for this study consists of approximately 600 seventh grade classes in 6 parish school systems in Northeast Louisiana. The selected classes receiving materials and equipment from the pilot study will serve as the experimental group for the study. Another seventh grade class, in the same parish school system and similar in status, will serve as the control group. This study will commence in the Fall. At the beginning of the academic year, both the experimental group and the control group will be administered a pretest for Attitudes Toward Science and a seventh grade criterion-referenced test. At the end of the academic year, both groups will be posttested on both the attitude survey and the criterion-referenced test. Data will be analyzed using paired t test and Oneway ANOVA for the pre and posttest scores on the Attitudes Toward Science Survey and the criterion-reference test and will be fused with results of the naturalistic component of the study.

SCIENCE SPECIALISTS, CLASSROOM TEACHERS, AND PRESERVICE EDUCATION MAJORS STAGES OF CONCERN TOWARD COOPERATIVE LEARNING

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This study examined the stages of concern toward cooperative learning of three groups of elementary education professionals: elementary science specialists, elementary classroom teachers, and preservice elementary education majors. Making use of data gathered with the 35-item Stages of Concern Questionnaire, comparisons were made of peak stages of concern. Preservice teachers were found to be predominately in the lower concern stages as they were just becoming aware of and developing an interest in cooperative learning. As a group, the classroom teachers were at the information gathering stage, although management of cooperative learning and awareness-seeking concerns were also high. The elementary science specialist, who taught science biweekly to fourth, fifth, and sixth grade classes in the district, had management as their peak concern, the stage at which they focus upon scheduling and organizational challenges. The number of years of teaching experience, for other than the preservice group, was found to be inversely related to individual advancement through the stages of concern. Teachers with more that the sample's mean years of experience had the most frequent concerns with obtaining additional information about cooperative learning. In contrast, teachers with less than the sample's mean years of experience were most concerned with managing the implementation of cooperative learning with their students. For both elementary classroom teachers and science specialists, when measured by peak stages of concern, the impact and consequences of cooperative learning on the students were of the least concern. Implications of the findings of this study for inservice programs on cooperative learning are provided.

HOW COLLEGE STUDENTS FEEL ABOUT ANIMAL DISSECTION IN LIFE SCIENCE CLASSES

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The use of live and preserved animals in educational life science investigations has been hotly debated in the literature in recent years. Several respected professional organizations have taken a stand on the issue and prominent educators have been persuaded to take supportive and nonsupportive positions on the topic. So politically explosive is the issue that several states have passed legislation requiring non-dissection alternative to be provided whenever experiments on animals occur in the classroom. Interestingly, little research has been conducted on the thoughts of students on the topic. To find their views, a survey on the issue was conduct at a mid-size eastern university on over two hundred undergraduates from a variety of academic departments. The survey consisted of a twenty-five item questionnaire containing questions on the use of live and preserved specimens. Several questions on the survey sought student reactions to dissecting organisms at various shylogenetic levels. Such factors as college major, age, and undergraduate year and gender were examined for each question and statistical analysis was applied to the test results to note significant differences on each item. The results of the analyses revealed that eighty percent of the students did not object to the dissection of preserved animals in life science classes. Second year students were the most supportive of the issue while participants in their final year of undergraduate study were the least supportive. Furthermore, both genders supported the issue with males favoring preserved animal dissection slightly more often that females. More than half of the students, however, would not support the use of live animals in life science investigations. Fifty-six percent of the students responded in negative fashion when asked about dissecting live, complex animals in biology. Interestingly, twice as many males as females defended the use of such animals in experimentation and research.

A TRIPHASIC MODEL OF THE TEACHING-LEARNING ENVIRONMENT BASED ON CONSTRUCTIVIST PRINCIPLES

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A model of the teaching-learning environment, based on cognitive-constructivist theories of learning, is presented. The model consists of three dimensions. Dimension One (Opportunity for Constructivist Activity) represents the proportion of teaching-learning activity that is directed to encouraging self-reflection, mobilization of individual cognitive representations, and integration of new learning within existing understandings of the students. The second dimension (Affect) is the relative amount of affective support provided by the teacher including recognition of student accomplishment, generally positive perspectives on the learning enterprise and supportive statements as opposed to aversive statements. The third dimension (Pace) is the tempo of classroom activity as assessed by the rate of teacher discourse and time between teacher solicitation and student response. The three dimensions are arranged in a triangular graph (bounded by the three dimensions) that permits localization of a teaching-learning environment within the field of the graph. The rationale for the model predicts that student perceptions of satisfaction with the learning experience will increase as the characteristics of the lesson place it closer to the vertex of the model categorized as constructivist. We have assessed the predictive validity of the model by coding tape-recorded lessons from six teachers who varied in style of teaching from more didactic toward constructivist. The lessons were mapped into the triangular field of coordinates based on the assessment of dimensions by three coders working independently (standard error of assessment = 0.04 to 0.06). We also obtained student perceptions of the lessons using a Likert-type device. The results of this study show that, as predicted by theory, lessons mapped closer to the constructivist vertex were rated more highly by the students for ease of understanding and positive emotional tone, compared to lessons that were removed, in the triangular field, from the constructivist vertex.

PROBLEM SOLVING IN PHYSICS AND MATHEMATICS - WHAT DO THEY HAVE IN COMMON? (CREATING A BASE FOR RESEARCH AND TEACHING)

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Problem solving in schools has been an important issue over decades. Research on problem solving has, however, always had certain limitations. It was mainly focussed on either the psychology of learning and teaching in general, or on one subject area such as mathematics, physics, chemistry or biology. However, because the natural sciences, and physics in particular, have been related to mathematics in their historical development and in some of their essential skills, and because in some schools these subjects are taught by the same teacher, possible commonalities in the domain of problem solving shall be explored. This study synthesizes the information available to date. It intends to provide a base for interdisciplinary research on the comparison of problem solving in these related fields at the middle and high school levels. Reviewing the body of published literature in the categories of research reports, as well as dissertations, books, monographs, position papers, and practical suggestions, shall help to give an overview of this interdisciplinary field of research in science education. The studies reported here are organized into groups as they relate to (a) problem solving as an activity (general, mathematical, and physical problem solving), (b) the learner and problem solving, and (c) the teaching of problem solving.

THE POSSIBLE RELATIONSHIP BETWEEN M-SPACE, DEVELOPMENTAL LEVEL AND GENETICS PROBLEM SOLVING IN PRESERVICE ELEMENTARY EDUCATION MAJORS

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As a part of an ongoing study of the complex relationships between M-Space, Piagetian development and problem solving ability, this poster will explore the effect of completing a series of activities requiring proportional reasoning on the ability to solve genetics problems predicted to have a range of M-demands. Ten classes of preservice elementary school teachers were randomly divided into two groups. The experimental group completed activities which were designed to require proportional thinking to complete successfully. The control group received control activities which were totally unrelated to the study, but were focused on drosophila M. anatomy, which was pertinent content to the unit. Both groups completed a set of genetics problems five weeks later, and the results for the two groups were compared. A random subgroup of students completed their problems in a think-a-loud setting. The think-a-loud problem solving sessions are being analyzed for comparisons of actual M-space used with expert predictions of M-demand for the problems. Additionally, these taped sessions are being analyzed for differences between a group who completed activities requiring proportional reasoning and a group who completed activities which did not.

CONTENT REPRESENTATION

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A study was conducted to determine how content was represented during curriculum enactment in a secondary environment science class. This qualitative study involved two analyses of the class data using academic tasks as the analytical framework. Several specific tasks are analyzed which reveal the nature of content representation in this class as subjective and issues-oriented. The findings reveal several features about the curriculum operating in this class which support this representation. It is suggested that task analytical frameworks be used to study the relationship between the nature of content representation and what students come to know about it.

STRATEGIES USED BY EXPERIENCED SCIENCE TEACHERS TO TRANSFORM SUBJECT MATTER CONTENT KNOWLEDGE INTO PEDAGOGICAL CONTENT KNOWLEDGE

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This study involved the examination of teaching strategies and tactics used by experienced teachers of chemistry and physics to transform subject matter content knowledge to pedagogical content knowledge so that the content was more easily understood by students. Teachers' perceptions of those concepts that are generally believed to give students the greatest trouble were investigated together with the teaching strategies employed to transform that subject matter into a form suitable for transmission to particular students in specific grade levels. Data were collected by means of open-ended interviews and lesson observations with two experienced teachers over a period of 10 weeks, seeking information about the variety of issues related to establishing links between conception of knowledge and specific pedagogical knowledge in the particular area of expertise, and examining the processes used to link subject matter content knowledge with pedagogical content knowledge. The two experienced teachers, one of whom taught chemistry and one who taught physics, taught in the same school which had a reputation for academic prowess in science although the school philosophy was to accept students with a wide range of backgrounds and competencies. The data were collected and analyzed in an ongoing manner, assertions were formed and modified as new data were obtained and analyzed. Upon completion of the study the following five assertions were made regarding the strategies used by the two experienced science teachers to transform their subject matter content knowledge to pedagogical content knowledge. (1) Experienced teachers do not regard formal lesson planning as a vital pedagogical strategy: experienced teachers plan in a more holistic fashion and these plans evolve, converge, or diverge with changing classroom circumstances. (2) Experienced teachers are guided by previous classroom experiences, but are not necessarily controlled by them. (3) Experienced teachers interact with a significant subject matter data base during the development of their lessons. (4) Reinforcement of concepts is regarded as an essential component of student learning; repetition and various question and answer strategies are the dominant reinforcement methods. (5) Experienced teachers utilize various presentation strategies but have favored representational repertoires and example schema. Experienced teachers add alternative strategies to their dominant repertoire to maintain and engage student interest. The findings of this study are useful to other experienced teachers and novice teachers who now have access to strategies which may help guide their own practice.

A COMPARISON OF MIDDLE SCHOOL TEACHERS' CONTENT KNOWLEDGE AND PEDAGOGICAL CONTENT OF HEAT, ENERGY, AND TEMPERATURE WITH THEIR STUDENTS' CONTENT KNOWLEDGE OF THESE CONCEPTS

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John Layman
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We traced development of four middle school science teachers' with respect to their content knowledge (CK) and pedagogical content knowledge (PCK) regarding heat energy and temperature concepts. We then compared the understanding of the teachers with the understanding of a small sub-sample of their students. Teachers took part in two intensive workshops, occurring during two sequential summers, that focused on use of microcomputer-based laboratory (MBL) curriculum materials in the middle school science classroom to teach heat energy and temperature concepts. Thirteen of the 22 teachers who participated in the workshops were randomly selected to take part in the research sequence. From these thirteen teachers, we selected four: two who demonstrated maximum growth in their content knowledge and pedagogical content knowledge after the second year of the study and two who demonstrated the least growth. Teachers used the MBL curriculum materials to teach heat energy and temperature concepts during two consecutive school years in their eighth grade physical science classrooms. They also develop activities during the workshops and school years to match their own curricular needs. Teachers differed in the extent to which they used the materials. Semi-structured interviews probed teachers' CK and PCK throughout a two year period. Interviews were conducted before the summer workshop on using MBL in the classroom, and at the beginning and end of the first and second school years. The semi-structured interviews served as the primary source of teacher data in this study. Classroom observations and curriculum materials, however, served as secondary sources of information. Semi-structured interviews that paralleled the content portions of the teachers' interview probed the students' understanding of heat energy and temperature. We interviewed four students from each teacher prior to the students' work with MBL and at the end of the school year during each year the teachers incorporated the MBL curriculum materials. In this paper, we focus on the student interviews obtained during the second year. Interview questions that focused on teachers' and students' content knowledge were analyzed using concept maps. The verbal data generated from PCK tasks were analyzed using a category system derived from the data. Our work suggests that science teachers content knowledge and pedagogical content knowledge grows and becomes more integrated and differentiated as a result of extensive preparation and classroom teaching experience.

IMPLEMENTING ACTIVITY-BASED LEARNING IN ELEMENTARY SCIENCE: LESSONS FOR POLICY-MAKERS AND SCHOOL SYSTEM LEADERS

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If one intends to implement activity-based elementary science in many different classrooms, the personnel involved almost certainly extend beyond the levels of teacher and principal. Based on the cross-site, cross-country analysis of the 15 case studies done in four countries, the following recommendations are offered to policy makers and school system leaders. Although grounded in the empirical finding of the case studies, they reflect the interpretation and professional judgments of the researchers as well. 1) Decide if elementary school science curriculum development and implementation will be school-based or a district-wide process. This question is not a simple one but is of first order importance. 2) The various leaders and policy-makers involved, not just district-level science specialists, should acquire a thorough understanding of the new approach under consideration, before proceeding with decisions related to it. 3) Do not proceed with the planned changes unless the key leaders and policy-makers are firmly committed to the change and have allocated the necessary resources over a long enough period of time that institutionalization of the change is likely to occur. 4) Develop thorough plans, allocate resources and establish competent leadership as needed, with respect to such aspects as the following - (a) Teacher involvement. Opportunities should be provided for teacher involvement in planning, materials development, and collaboration with other teachers. (b) Materials Development. Materials can be selected as an extant package, selected as components and integrated into a local program, or developed locally. (c) Inservice education. Sufficient and appropriate inservice education for both principals and teachers is needed. (d) Equipment and supplies. Provision must be made for equipment and expendable materials. (e) Individual assistance for teachers. Individual teacher assistance should be provided in some manner. 5) Once the plans and leadership are in place, it is time to "work the plan" with a long-term commitment. A program of this nature requires forms of maintenance different from more conventional programs. 6) Policy-makers and leaders at all levels (national, state and local) need to communicate effectively with the public about the changes underway. 7) They need to provide financial incentives for exemplary practice including appropriations for trying new ideas and supporting and continuation of successful changes. 8) Evaluation needs careful attention including dissemination of the results of past research.

ORIGIN AND METHODOLOGY OF IMPACT - INVESTIGATING THE IMPLEMENTATION OF ACTIVITY-BASED LEARNING IN ELEMENTARY SCIENCE

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IMPACT is a comparative research study in the following countries: Germany, Sweden, The Netherlands, and the United States of America. It is an acronym for Implementing Activity-Based Learning in Elementary Science Education. The lecture concentrates upon the origin and methodology of this international project whereas other members of IMPACT describe interim findings and lessons for school improvement and policy-making. Two motives build the central concern: firstly, to investigate the process of institutionalization that follows the introduction of an innovation, and secondly, to explore the sustained use of activity-based learning in elementary schools by means of qualitative data analysis and cross-case comparison. The research framework emerged from interdisciplinary cooperation of researchers from the following institutions: Kiel Institute for Science Education, Germany, University of Twenty, the Netherlands, University of Colorado, USA, and the University of Goteborg/Karlstad, Sweden. Each of the 15 schools/cases out of four countries were studied over roughly two weeks, many of them even over a longer time-span. Our comparison is based upon classroom observation, repeated interviews of school leaders, involved teachers and other staff, interviews with students, analysis of instructional materials, photographic documentation of the learning environment, and other.

IMPACT RECOMMENDATIONS FOR SUPPORT PERSONNEL

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Of the many variables determining the process and outcomes of the implementation and institutionalization of changes in the elementary science curriculum, some are easier to influence than others. External support activities, especially curriculum development and in-service training, being the first category. In the analysis of the IMPACT cases we have found both common and unique characteristics of these support activities. In this paper we shall present several recommendations for support strategies, based on a combination of our empirical findings and the innovation literature. The main topics will include: 1) characteristics of effective curriculum materials; 2) strategies for the implementation of these materials; 3) the design of in-service training; 4) the combination of internal and external support; 5) fostering staff development within the school; 6) networking between schools.

INVESTIGATING THE PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS: VIEWS FROM A SCIENCE SUPPORT TEACHER PROGRAM

(OVERVIEW OF PAPERSET)

The proposed symposium will address the study of the professional development of science teachers by presenting different aspects of doing that study. The whole symposium will accomplish this by drawing on the study of a Science Support Teacher Program now in its third year of implementation. The first paper will verily describe the architecture of the program and its history up to this moment in order to contextualize the subsequent presentations. The second paper takes a look at the efforts and results of documenting and studying the intervention from the points of view of a program staff member and a support teacher. The third paper looks at how the process of documentation and study made possible the questioning of practice in one of the teachers. The fourth paper looks at the transformations of the support teachers' ways of teaching and interacting and at the role of research in that process. The fifth paper looks at studying the change in the vision, skills, and techniques of the support teachers as a result of the program. Finally, the sixth paper looks at the ways a teacher makes sense of educational research in order to improve his practice and make it communicable to other practitioners.

FRAMING THE SCIENCE SUPPORT TEACHER PROGRAM: CONTEXT, HISTORY, ASSUMPTIONS, TRAINING, AND TECHNICAL ASSISTANCE

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The Support Teacher Program was formulated as a cooperative project between a major research university, a national teachers' union, and an urban school district to apply the findings from research on teaching and learning to the improvement of junior high school students' understanding of science. Beginning in 1987, university science educators worked with officials of the teachers' union and the school district to formulate a plan of the establishment of a new professional role in schools--that of the Support Teacher. Nominees for the new role were to be assisted in (1) acquiring new knowledge from research on teaching and learning (2) learning how to apply this knowledge to improve their own teaching and their students' learning, (3) learning how to assist their peers in acquiring and applying the knowledge to improve their teaching and students' learning. Four science and four mathematics teachers in four junior high schools in an urban school district were chosen as Support Teachers with the consensus of administrators and peers. Support Teachers received training through formal seminars and on-the-jobs experiences for a period of eight months before assuming their new role, and training continued for two years beyond initiation. Training tended to be problem-focuses; that is, as new concerns surfaced, these became the basis of analysis and study by the group members. Data from documentation include audio tape records of the training session; formal interviews with, and questionnaires completed by the Support Teachers and administrators; questionnaires completed by other science teachers in the four schools; a daily journal kept by Support Teachers which chronicles activities and events in their respective departments; records of observations and feedback sessions by Support Teachers and their peers; observations during three week-long periods of external observers to further document and change that were occurring in the departments; and data on changes in students' understanding of science. Results show that Support Teachers have made important changes in their "vision" of science teaching and learning, and their classroom practices also have changed dramatically. There is a greater emphasis on teaching for understanding and a reduction in emphasis on content coverage. New teaching strategies are used to enhance students' understanding and ability to apply science. Departmental climate has changed, so that teachers focus less on student control, and give more emphasis to matters relating to teaching and students' understanding. Last, and most importantly, student achievement has begun to improve classrooms where teachers have made changes. Subsequent papers in this Symposium will highlight the specific nature of the changes that occurred as a consequence of the Support Teacher Program.

THE DOCUMENTER AND THE DOCUMENTED LOOK AT CHANGE IN JUNIOR HIGH SCHOOL SCIENCE

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McTigue Junior High School
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This presentation highlights the process of documentation used by collectors of the data which is analyzed to provide evidence for the asserted changes in Support Teachers, their peers, and the students. Given the nature of the program, multiple sources of data are used: Support Teachers' logbooks and files documenting work with their peers; documents relating to work in the science classroom; student-generated text ranging from short responses to essays; and tapes of science lessons and feedback sessions from science teachers. Both the variety and extensiveness of this documentation poses several problems for the project staff and Support Teachers. One of the problems that will be addressed is that of analysis of these multiple forms of data and generation of findings from them.

ANOTHER PAIR OF EYES: ON THE REFLEXIVITY OF THE ETHNOGRAPHIC OBSERVATION OF A SCIENCE TEACHER

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Lucille Vernile
DeVeaux Junior High
Toledo, OH

As part of a major effort towards the documentation of teachers' roles, in a project aimed at restructuring those roles, one female science teacher was ethnographically observed while performing her daily teaching, department management, and peer-supporting task. This observation was performed during the winter and spring of 1989. The technique used was called "shadowing", since both the observer and the subject were together for long periods of time each day. Jointly written by the observer and the observed teacher, this paper's aim is to analyze this "shadowing" technique both as a research tool and as a medium for the teacher's critical examination of her practices. The paper addresses, in detail, the description of the technique used, the teacher's and student's reaction to the observation, and post-observation effects on the teacher's practices.

A LOOK AT SCIENCE TEACHERS' BELIEFS ABOUT TEACHING AND LEARNING

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This paper presents a study of science Support Teachers' change of vision, and teaching skills and techniques as a result of the Support Teachers Program. Data were collected by interviewing each of the four science Support Teachers, scrutinizing their logbooks of daily activities and audiotapes of science lessons of each teacher. Data analysis involved comparing and contrasting the responses to the interview questions, the entries in the log book, and the structure of their science lessons. The findings support the conclusion that changes in vision and practice occurred and that some of these changes were radical. Teachers use more elicitation of students' thinking, more open-minded questions, an extended wait-time, cooperative small group instruction, more writing of students own ideas, less breadth of content with greater depth, more active involvement of students, and so forth. The change in vision is more profound than the changes in practice, as expected.

TALKING LESS AND LISTENING MORE: AN INTEGRAL PART OF RELATING TO STUDENTS AND PEERS THE TOLEDO SUPPORT TEACHER PROGRAM

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The goal of the Support Teacher Program has been to improve the learning of math and science concepts at the junior high school level. This goal involves some basic changes in the way teachers interact with each other and with their students. The changes require teachers to move from traditional to non-traditional practices and to become more reflective. The greatest changes have been in the movement away from the lecture-note taking-test taking cycle and in overcoming teaching isolation. The research contributed by Nussbaum, Roth, Anderson, and others on conceptual understanding and misconceptions was the "hook" that forced us to alter our teaching styles. Cooperative learning, different questioning techniques, extended wait time, inter-student discourse, and increased writing are many of the tools being used by Support Teachers and peers. As a result of these changes, there have been positive interactions occurring among students and peers. In addition, the aforementioned techniques have provided a vehicle for achieving this vision of teaching for understanding. Less teacher talk and more listening will lead to more teaching!

FROM THE CLAWS OF SCILLA INTO THE TEETH OF CHARYBDIS: TALES OF A TEACHER MAKING SENSE OF SCIENCE EDUCATION RESEARCH

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From mythology we remember the reference to the Scylla and the Charybdis, either to be devoured by the monster on the rocks or to be sucked down by the whirlpool. In everyday speech this phrase has taken on the meaning of having to make a choice between two unpleasant options. It is well understood that the world of the teacher and the world of the educational research are very different. At first glance it would seem that the relationship between the two would be quite cooperative due to a common goal; that is, a better education for the students involved. That isn't always the case. There is a cycle of misunderstanding and accusation that comes with the relationship as well. Researchers sometimes suggest that the schools would be better places and that students would learn more if the teachers would just read and apply more current research. On the other hand, many teachers believe that the researchers don't tell them anything other than what is wrong. Hence the title: the two groups involved speak past one another, they have different journals, and they each see the other as a group that is uninformed as to the "true" nature of life in classrooms. Flung headlong into this controversy was a teacher that was assigned by a national teachers' union to study educational research and the way that researchers operate, so as to design a handbook for teachers which would help them acquire, understand, and apply current educational research findings about classroom practices, student understanding, and student achievement. This paper covers several aspects of the year that the teacher spent with the researchers at the university. First of all, the article documents the sense-making process that the teachers went through, how his thinking changed and stayed the same at different points, and how both the teachers and the researchers with whom he worked were challenged and stimulated by the experience. Secondly, the teacher's comments upon being caught between the world of classroom teachers and educational researcher are discussed in his own words. Thirdly, a discussion of how the teacher sees that year has made a difference is his life is presented. This is an important paper in this symposium because it gives the audience of mainly educational researchers a chance to hear, from a teacher's point of view, what is important to teachers about educational research.

A CONSTRUCTION OF THE ACTIONAL DIMENSION OF CHILDREN'S SCIENCE

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This paper reports on a study of an actional dimension of children's science namely tinkering. Osborne & Freyberg (1985) describe children's science by noting that some children's views of the world and meanings for words are unexpectedly different from those of adults in general and scientists in particular. Those views and different work meanings influence children's subsequent learning in science. Most studies investigating children's science have focused on children's conceptualization of scientific phenomena. The present study however brought a wide perspective to children's science by seeking to also describe it as the intuitive methods which children learn from everyday experience. The findings therefore add new dimension to the study of children's science by providing insight into the methods by which some children may acquire their intuitive knowledge of selected science concepts. The results of the study offers this clarification by the way of proposing a model of tinkering. It attempts to clarify the nature of tinkering and how it might be related to the development of an understanding and interest in science. Based on results from preliminary and pilot studies ten target students were selected for the purpose of data collection. Subsequently six target subjects, representing a variety of levels of tinkering, were selected for final analysis. The analysis utilized a variety of data sources (survey, interview, and classroom observation) collected over a three month period. A model of tinkering was constructed which conceptualizes tinkering as consisting of three general sets of characteristics. These characteristics were described in terms of the different types of tinkering observed, the different phases entailed in the tinkering process, and finally the different types of knowledge generated by this activity. The first characteristic, called the 'a typology of tinkering', maps out the 'purpose' and 'proficiency' of tinkering as it was observed in the target subjects. Four purposes were described: utilitarian, technological, scientific, pragmatic. The proficiency of tinkering was described in terms of categories: master, professional, amateur and novice. The second characteristic focussed on the nature of the process of tinkering. Tinkering was conceptualized as a form of problem-solving, with four different phases of tinkering activity. A third characteristic was the kinds of knowledge bases that appear to be constructed from tinkering activity. These were described in terms of verbal and actional knowledge. Another dimension of the model which was constructed includes three sets of factors: experimental, social and personal. These factors were metaphorically described as an apprenticeship. The experimental factors were noted as ranging from low to high levels. The social factors were described as having three levels of influence, namely mentor, family and friends, and school and other agencies. The personal factors were described as ranging from low to high levels of interest.

CLES: AN INSTRUMENT FOR ASSESSING CONSTRUCTIVIST LEARNING ENVIRONMENTS

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Over the last decade, there has been increasing research emphasis on the epistemological assumptions underpinning the classroom learning environment. Recently, developments in history, philosophy, and sociology have provided educators with a better understanding of the nature of knowledge development. For example, the new history and sociology of science movement has revealed the tentative and metaphysical nature of scientific theories, which gain temporary affirmation from processes of social negotiation and consensus making amongst the community of professional scientists. At the level of the individual learner, there has been a realization that meaningful learning is a cognitive process of making sense, or purposeful problem solving, of the experiential world of the individual in relation to the totality of the individual's already constructed (cultural, scientific, mathematical) knowledge. A new learning environment instrument is needed to assist researchers to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and reshape their teaching practice. The Constructivist Learning Environment Survey (CLES) was developed to meet this need. Four scales were developed to measure important aspects of a constructivist learning environment. The Autonomy scale measures perceptions of the extent to which the learning environment provides opportunities for students to develop their own ideas in the classroom setting, think independently of the teacher and other students and exercise control over their learning activities. The Prior Knowledge scale measures perceptions of the extent to which the learning environment provides opportunities for students meaningfully to integrate their prior knowledge and experiences with their newly constructed knowledge. The Collaboration scale measures perceptions of the extent to which learning environment provides opportunities for social interaction amongst the participants for the purpose of negotiating meaning and building consensus. The Reflection scale measures student perceptions of the extent to which the learning environment provides opportunities to engage in reflective thinking. The present version of the CLES contains 40 items in both perceived and preferred forms. Each item has a five-point Likert format with responses of Very Often, Often, Sometimes, Seldom, and Never. A total of 10 teachers and 450 students completed both the perceived and preferred forms of CLES. Scales were found to display satisfactory internal consistency and discriminant validity, and to differentiate between the perceptions of students in different classrooms, for samples from the USA and Australia. When comparisons were made of the teacher and student responses to the CLES, results replicated previous learning environment research in that generally teachers held more favorable perceptions than did their students in the same classrooms.

THE INFORMATION-CONSTRUCTIVIST (I-C) PERSPECTIVE APPLICATIONS TO AND IMPLICATIONS FOR SCIENCE EDUCATION

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Constructivism, as a conceptual framework for describing and explaining human thinking, learning, and development, is emerging as a, if not the, dominant paradigm in science, at least among the major theorists and researchers in science education (von Glasserfeld, 1990). However, the present constructivist perspective lacks a great deal of clarity and definitiveness that would enable far more educators to acquire and use this perspective in their research, curriculum planning, instruction, and assessment of student learning. A concern is how does one take the constructivist view and convert it into a clearly articulated, less abstract, and very practical knowledge base for application at all levels. This paper describes one particular conception of constructivism, i.e. the information-constructivist perspective, as a viable and extremely functional framework for science educators. This paper describes the essential elements of the information-constructivist perspective; defines relevant terms and concepts within this construct of human cognition, development, and action; addresses the notions of infoschemata, beliefs, invention, construction, validity, knowledge, and understanding within this perspective; and, describes a set of implications of and a set of practical applications of this particular perspective for science education. Initial constructs of constructivism were augmented or revised to enable them to be extremely comprehensible and useful. Additional constructs were added and their functions and contents described so that a unified model of constructivism consistent with information processing theory emerged. Three critical learner-learning variables were used to "reconceptualize" and clarify many of the constructs and principles associated with prevailing conceptions of constructivism used within the science education community. The I-C conception of: "infoschemata" as clusters of interrelated sets of information which individuals invent, construct, refine, augment, apply, test, and verify is a case in point. There are at least 18 characteristics that all infoschemata seem to share. In addition, these clusters of information serve as the data base for one's cognitive beliefs, orientations, and perspectives. Details of how infoschemata are invented, constructed, revised, augmented, etc. are presented. To be included are descriptions of major theoretical I-C constructs such as : infobits; infoschemata; cognitive-beliefs; knowledge; memory; storage; processing events; validity; invention; and learning. Nearly all of these constructs have unique definitions within the I-C view. Applications and implications of this perspective for science educators include what it means to plan for and enable students to acquire appropriate infoschemata relevant to science; how to help students move away from current conception-beliefs associated with phenomenon in science and toward appropriate conceptions-beliefs; and how and why certain models of "inquiry teaching", including the "teaching/learning cycle model", as currently conceived, are likely to be incomplete in helping learners acquire and use accurate conceptions while revising or changing misconceptions.

COMPUTER-VIDEO-BASED ACTIVITIES TO FACILITATE LEARNING IN GEOMETRICAL OPTICS

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A series of computer-videodisc-based learning activities in the domain of geometrical optics have been developed. The development was guided by constructivist principles and by previous research on student learning. The activities have been integrated into an activity-based physics course for prospective elementary and middle school teachers. The cornerstone of the instructional environment is a locally-produced videodisc. It contains a large number of demonstration tasks asking the viewer to make predictions about a wide range of phenomena in the domain of geometric optics. The activities incorporate several strategies that prior research suggests will promote student learning. These strategies include the following: (1) New knowledge builds on prior knowledge. Many of the tasks presented via the video are designed to elicit prior knowledge. (2) Collaborative learning. Students, working in pairs, discuss the task questions and make joint decisions on construction of ray diagrams. (3) Need for new knowledge emerges in a problem-solving context. As students work through a sequence of tasks and receive feedback they develop a need to construct new ideas, which can then be tested in subsequent tasks. (4) Dual encoding of information. To facilitate making connections between real world optical phenomena and diagrammatic representations of those phenomena the students use a mouse-controlled cursor to construct light ray diagrams on top of video pictures of optical apparatus. Also, all optical scenes of phenomena are presented to the students with two simultaneous views: and "eye view" and an orthographic view. (5) Focus on a limited number of powerful ideas. As important ideas are developed, students save them in an electronic notebook. They use these ideas to guide new predictions and diagram constructions. The activities have been used in a classroom of twenty-eight students using fourteen Macintosh II-videodisc workstations. Student understanding of optics developed in this environment will be assessed and compared with student understanding of optics developed in a more traditional learning environment.

MICROCOMPUTER-BASED LABORATORIES AND COMPUTER NETWORKING IN HIGH SCHOOL SCIENCE CLASSROOMS

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Microcomputer-based laboratories (MBLs) are believed to have significant potential for improving laboratory experiences in science classrooms. Previous research, conducted mostly with junior high school and middle school students, indicates that MBLs can result in significant improvement in students' graphing skills. The real-time graphing capabilities of MBLs are credited with this improvement. This study, funded through a grant project called STEPS to Better Science, seeks to broaden the research base by examining MBL use by students in a variety of science classrooms in six high schools in Indiana. The use of MBLs in "real-world" science classrooms is examined through triangulation of several data sources. Data collected includes: school demographic information, student and teacher attitudes toward the use of MBLs, student graphing performance, and classroom observations of the use of MBLs. Of additional interest is the use of a larger-scale computer network for project data sharing, resource acquisition, and communications. The study is being conducted during the 1990-91 school year.

AN ANALYSIS OF TERC STAR SCHOOLS NETWORK COMMUNICATIONS

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Purpose: Technical Education Research Centers (TERC) has led in the effort to give direction to how technology can be used in math and science education. Their orientation has been toward the development of hardware, software and curriculum materials that put technology at the service of students, and the students in the role of investigators. TERC lead in the development of micro computer based labs (MBL) hardware and software and, in the National Geographic Kids Network program TERC began developing the concept of network science. In the Star Schools project, TERC has built on this prior work. The purpose of this study is to address the question of how a network is used within the context developed by TERC in the Star Schools project. Significance: The goal of involving students in the role of scientists has characterized much of our effort in science education. As a new technology is introduced, and a use of that technology that proclaims this goal, it is important to look at the ways that the goal is achieved, and where there needs to be further emphasis. Procedures: All the mail sent by three clusters of schools carrying out radon investigations represents the data for analysis. There was a total of 46 classes in these three. Cluster A had an average grade level of 10.2 for classes that sent mail, the Cluster B average grade level was 7.5 and Cluster C was 7.7 Bellack's (1968) pedagogical moves were used as the basic unit for analysis. These were coded in terms of who made them and what the content was. Following Bellack, meanings were dichotomized: those that communicated subject matter, substantive meanings, and those that did not, which are said to have instructional meaning. Results: Of the 46 classes, 24 were able to get on-line and send mail. Of these, 13 sent mail over ten times. Cluster A had the most participating classes, nine, while Cluster B had eight and Cluster C had seven. Cluster A was more active that the others, making over 50% of the moves. They also had the most active Cluster Chair, a role whose function is to stimulate cluster activity. The Chair for Cluster A made 47% of all cluster chair moves. Most of the moves were made among teachers, cluster chairs, and TERC, 61%. The remainder were made by individual or groups of students, or the class, a unit including the teacher.

CONCEPTUAL CHANGE INSTRUCTION
(OVERVIEW OF PAPERSET)

A model of learning as conceptual change was developed by Posner et al. (1982) at Cornell University in 1978-9 and expanded by Hewson (1981). The two major components to the conceptual change model (or CCM) are the conditions (intelligibility, plausibility, and fruitfulness) to be satisfied for a person to undergo conceptual change, and the person's conceptual ecology that is used in determining if conditions are satisfied. The status of a conception, in the CCM, refers to the extent to which the conception meets the conditions. Even though the conceptual change model (CCM) is a learning model, and therefore is not prescriptive of instruction, the potential links between the CCM and science instruction have been explored by different people in different ways. Some have used the CCM as a basis for designing a variety of instructional strategies and practices. Other have designed instruction in other ways and have sought to use the CCM to analyze and/or justify their design. The purpose of the proposed paper set is to address in different ways the question: What is "conceptual change instruction?". A recent review (Hewson & Tohorley, 1989) showed that, while several investigators have made explicit use of the CCM in the design of instructional sequences, the specific relevance of the CCM was often unclear because the nature of the learning interaction was difficult to judge from the published accounts. Without such data the model, as a learning model, cannot be considered to have been properly tested. This points to the need to conduct studies that explore the possibility of making the status of students' conceptions an explicit part of classroom practice. The first two contributions to the paper set address this need. The review also showed that many classroom studies had followed general constructivist principles without necessarily using the CCM in an explicit fashion in their design. These studies can nevertheless be regarded as examples of conceptual change instruction in a broad sense. The third contribution to the paper set is a study of this kind. The final contribution reviews these studies, as well as earlier ones, with the goal of synthesizing some general principles of conceptual change instruction.

CONCEPTUAL CHANGE INSTRUCTION

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This paper presents some general conclusions that emerge from a review of studies of conceptual change instruction, some explicitly using the conceptual change Model (Posner, et al. 1982). First, conceptual change instruction is marked by (1) different phases, such as elicitation (students' views are identified and become part of the classroom discourse), status-lowering (direct contrast of views shows that some are more viable than others), and status-raising (in which appropriate conceptions explain common events and are applied to new situations); (2) a classroom climate in which students can express divergent views without sanction, and the goal of discourse in the achievement of shared meanings, chosen because they make sense to participants; (3) teachers who are able to establish the classroom climate outlined above (thereby removing themselves as the ultimate authority), and who play many roles such as setting appropriate contexts for classroom activities, exploring what underlies different ideas without threat to those who hold them, finding ways of helping students become dissatisfied with their own ideas, and knowing when and how to introduce scientific conceptions; (4) learners who accept that understanding should be the goal of learning, who accept responsibility for their own learning, who trust their own thinking, who recognize that there might be different views of similar events, who respect the views of others, and who are prepared to change their views; and (5) the presence of a metacognitive component to the classroom discourse in which not only the scientific conceptions but also the status of those conceptions in the minds of the students are an explicit part of the discourse.

THE DEVELOPMENT OF A FRAMEWORK BASED ON THE CONCEPTUAL CHANGE MODEL FOR THE INTERPRETATION OF SCIENCE CLASSROOM DISCOURSE

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The Conceptual Change Model (CCM), formulated a decade ago to illuminate the role of students' existing ideas in learning, was based on an analogy between students' conceptual learning in classrooms and processes of conceptual change in scientific communities. The central construct in the CCM, determining whether a conception can be learned, retained or rejected, is the status of a conception as seen by the learner. A conception has low status if it is only intelligible, moderate status is intelligible and plausible, and high status if fruitful as well. A literature review has shown that although the CCM has been extensively cited, no reported classroom implementations have attended to status. In classroom learning based on the CCM, an essential feature of discourse should be the occurrence of status-related interactions (SRI's). This study sought to identify and describe SRI's in discourse samples from science classrooms having conceptual change orientation. Recordings were obtained from classrooms of three physics teachers addressing "force and motion", and one life science teacher focusing on "photosynthesis". The possible nature of SRI's and the interpretation of status and the CCM itself were found to be problematic, necessitating a conceptual analysis of the model. The analysis concluded that first, the notions of "conception" and "representation" should be distinguished, second that the "status" is a multi-dimensional construct, and third that non-rational but cognitive forms of learning should be addressed. A category system was developed using a revision cycle during the initial application phase. The system is used for analyzing content in science classroom discourse. It reflects the two main dimensions of SRI's, one metacognitive, the other the revised status construct, which emphasizes the notion of a conceptual ecology. Application of the system to discourse samples from science classrooms resulted in the identification of SRI's exemplifying a wide spectrum of the categories. This analytical system has the potential to facilitate description and interpretation of the content of science classroom discourse, complementing approaches to discourse analysis focusing on generic and structural patterns of communication. It has potential for both future research and the education of science students and teachers.

CONCEPTUAL CHANGE ANALYSIS OF SIXTH GRADER STUDENTS' ABILITY TO DISCUSS THE STATUS OF THEIR CONCEPTIONS OF FORCE AND MOTION

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Presented is an analysis of a status revealing technique which required the students to learn the technical language of the conceptual change model (CMM) with sufficient familiarity that they could talk about the intelligibility, plausibility, and fruitfulness of their own conceptions. This metacognitive process required 6th grade students to reflect on and talk about, not only the science concepts (force and motion) they hold and why they hold them, but also the status of these conceptions within their own minds.

EXTREME CASES AND MODELS IN STUDENTS' LEARNING

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Seventh grade children's reasoning about levers and simple machines were investigated. In particular, issues such as the young students' naive conceptions, their reasoning in response to specific instructional techniques and learning as a result of the latter were studied. The study was comprised of several cycles of design, test and clinical interview tutoring sessions. In this report the effects of an instructional sequence, based on extreme case reasoning will be presented. Analyses of students' protocols (N=12) indicate that the strategy was successful in levers, evident in the students' ability to transfer their acquired principles and models to difficult, complex and compound "real" levers and in conceptual changes apparent in the pre-posttest "simple levers" questions. The findings from the study suggest that research on instruction that employs experts' non-formal reasoning strategies, such as extreme case or limiting case reasoning should be encouraged.

BEHAVIOR AND ATTITUDE OF SCIENCE EDUCATION GRADUATE STUDENTS: A CASE STUDY

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This study identifies the behavior and attitude of three science education graduate students assigned to two different science education professors. These professors taught separate sections of the same science methods course at a university. The symbolic interactionist and functionalist positions are taken as a theoretical perspective. From the symbolic interactionist paradigm, meanings are attributed to the behavior and attitude of the participants. From the functionalist paradigm, a structure identified by an outside researcher can be used to explain these processes. Categorization of behavior and attitude of the graduate assistants according to the participants' perception and to the relationship with their assigned professors reveals the function of their behavior and attitude in relation to other parts of the social system. Data collection methods used were qualitative, individual interviews and participant observation. Analytic induction was performed in the constant comparative procedure to examine the data collected. Data were first chunked into categories for each graduate assistant according to personal background, organization of the science methods course, and the behavior and attitude related to the individual's association with the science methods course. The behaviors and attitudes of the graduate assistants were then arranged in two matrices, one showing behavior and the other attitude, to contrast different sections of the science methods course taught by different professors. Patterns of similarity and differences in the behaviors and attitudes of the graduate assistants recognized in the data became analytic concepts, the constructs. The constructs for graduate assistant behavior were professor-prompted behaviors and career-prompted behaviors. The constructs for graduate assistant attitude were loyal follower, drafted worker, and critical constructor. Insights emerging from this study suggest that there is an interaction between the organization of the science methods course, the education philosophies of the professors teaching the different sections, and the career goals of the graduate assistant. The result is differences in behavior and attitude exhibited by the assigned graduate students, some of which is arguably not beneficial to their professional development or to future improvement in science education methods courses. Generating theory is the aim of this research, although the resulting insights are meaningful in similar contexts.

THE ROLE OF FACULTY PHILOSOPHIES ON THE TRAINING OF SCIENCE EDUCATION DOCTORAL STUDENTS: A CASE STUDY

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The purpose of this study was to identify and determine the role of faculty and institutional philosophies on the preparation of doctoral students in science education. An interpretive case study method was used to address this from a phenomological perspective. The scope of the study was the science education emphasis within the curriculum and instruction doctoral program at Kansas State University. Purposeful as well as theoretical sampling was used so that the most important information about the problem could be delineated and so that these data could serve to guide the investigator to the next source of information so that a theoretical perspective could emerge. The researcher was the primary instrument in the data collection process. Informal interviews; qualitative content analysis of documents such as course syllabi and philosophy and goal statements; and participant observation in various functions such as seminars, defenses, and advising of students were all used to triangulate data.

A CASE FOR EXPLICIT UNDERSTANDINGS

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The literature of science education represents many diverse areas of concern, containing articles ranging from descriptions of misconceptions in a host of content areas through experiments testing the learning cycle to examinations of the role of attitudes in student decision making. The messages these diverse research areas communicate to the up-and-coming new practitioner are often confusing and contradictory, a situation which more explicit descriptions of concepts and ideas may be able to correct. One area of particular concern centers on science educators' description of the nature of science. Science has been radically redefined by philosophers in the last quarter century, and yet the literature in science education repeatedly reports that teachers as well as students are oblivious to the modern view. Do graduate students in science education similarly lack an informed understanding of the scientific enterprise, a commitment to a representational perspective, and a familiarity with the methodology of justification? If we accept the commonly stated relationship between teacher and student, arguing that teachers' understandings influence the understandings of their students, then we must accept the proposition that the understanding of teacher-trainers influence their students, who as the teachers of the future will in turn influence many more individuals. This compounding effect makes it essential that graduate students intending to make science education their career come to grips with their own sets of assumptions and presumptions. The task is by no means a trivial one. Some questions that might help us to reflect on our views indicate the difficulties in such a reflection. How do science education graduate students describe the nature of science? How do we view the nature of knowledge and how familiar are we with alternative views? What, if anything, controls the learning process, and what role do we see for a discussion of the relationship between theory and evidence in science teacher training? As graduate students in science education, we need to inform our own practice as well as that of science teachers and science professionals. Our implicit understandings are often not clearly stated, neither for others nor for ourselves. This leads to needless misunderstanding and confusion. Part of the process of professionalization is the adoption of a paradigm in Kuhn's classic sense, a paradigm of language and understanding familiar to other professionals in the area of study. This is not to say that all science educators should share a common understanding of difficult concepts like the nature of science, but we should at least be able to state explicitly our own particular interpretation.

ATTITUDE OF GRADUATE STUDENTS TOWARD ACADEMIC EDUCATION AND RESEARCH IN SCIENCE EDUCATION: A CASE STUDY

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The purpose of this case study was to investigate the attitudes of science education graduate students toward their academic study and research activities as well as to identify the critical factors influencing their attitudes. Four science education graduate students enrolled in master degree courses at the University were involved in this investigation. Qualitative descriptive data were collected using self-evaluation questionnaire cum individual interview. The instrument used for self-evaluation was a descriptive questionnaire comprised of two sections. The first section assessed student attitudes and focused on the following: (1) motivation toward graduate studies; (2) reason for the selection of research fields and theme; (3) attitudes toward academic course works related to the specialized science subjects and science education; (4) attitude toward research activities for master degree's theses; (5) and perspective on future career. The second section of the questionnaire focused on the identification of the critical factors influencing the total attitudes described in the first section, and prioritizes the factors identified according to the extent to which they influence the students' attitudes positively and negatively. For the limited negative factors identified and prioritized, possibilities for the improvement of each factor are also considered by individual students in terms of the constructive views. Results of this study might suggest that motivation toward graduate study, research theme selection, attitude toward course work, attitude toward research activities, and career perspective possessed by science education graduate students are inter-linked both in positive and in negative manner. As a fundamental and prerequisite condition for obtaining positive attitudes toward graduate study and research, the students need to be cognitively well prepared in knowledge and skills which they are supposed to acquire in undergraduate courses. Critical factors most influencing the attitudes appeared to be a daily-base incidental personal one rather than an intended and planned instructional one. Therefore, among personal factor, the role of academic advisors seems very important to facilitate, monitor, evaluate, and give the students appropriate feedback not only through the formal instruction but also through the informal one, so that the students can reflect critically on their works and construct the positive view for the advancement of works, thus ultimately they can be cognitively independent. A flexible and open-minded atmosphere needs to be set up to promote the development of creativity in students. This kind of case study can provide prescriptive data for the improvement of advanced teacher education and research training in science education at graduate school level.

CASE STUDIES OF SESAME (SEARCH FOR EXCELLENCE IN SCIENCE AND MATHEMATICS EDUCATION) AND EMST (EDUCATION IN MATHEMATICS, SCIENCE, AND TECHNOLOGY) GRADUATE PROGRAMS AT THE UNIVERSITY OF CALIFORNIA BERKELEY: INTEGRATION OF PHILOSOPHY WITH CURRICULUM, LEARNING, AND TEACHING

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Two similarities of two graduate programs in science and mathematics education will be explored. This exploration will include mechanisms for integrating program philosophies in the curriculum, learning, teaching, and general culture of a community. The programs considered are the SESAME (Search for Excellence in Science and Mathematics Education) Interdisciplinary Graduate Group and the Graduate School of Education's EMST division (Education in Mathematics, Science, and Technology). SESAME was created to enable individuals with a strong science or mathematics background (master's degree in science or mathematics required for admission) to integrate their domain knowledge with recent advances in cognitive science. EMST was explicitly designed to pioneer a new scientific approach to the study of education and to serve as a model for other such programs. Both of these programs were built on an intellectual promise: that the emerging field of cognitive science, the interdisciplinary study of the workings of the mind, could yield the kinds of rigorous knowledge about the nature of thinking and learning processes that would allow for the development of a principled scientific practice of education, where practice is consistently informed by basic research. Both programs are devoted to basic research, to establishing a scientific basis for understanding cognition and education, and to the epistemological assumption that a great deal of interdisciplinary knowledge is required to understand complex problems of teaching and learning. This presentation will explore how the fundamental philosophies of these programs are embedded in the "apprenticeship" model used in coursework requirements and research.

TEACHERS' BELIEFS AND CLASSROOM INTERACTIONS: LESSONS FROM HIGH SCHOOL CHEMISTRY

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Improving science education K-12 has long been a challenge for the people of the United States. This study focuses on the relationship between science teachers' beliefs and what goes on in their classes. Since the intent of the research was to view the classroom interactions from the teachers' perspective, qualitative methods were employed. Two high school chemistry teachers were chosen to participate in the research. They were chosen based on their involvement in innovative projects, their willingness to communicate with the researcher, and their years of experience in the classroom. The participating teachers had 18 and 24 years of experience in the classroom respectively. Interviews with each of these teachers served as the primary data source for this study. Four formal interviews were conducted with each teacher throughout the fall semester. More informal interview data were collected daily after the observation of a class. Secondary data sources included daily observations over the course of the Fall 1989 semester, student interviews, interviews with school officials, and analysis of classroom artifacts. These data were used to construct case studies of both of the participating teachers. The two teachers had very similar goals for teaching high school chemistry and they used the same adopted curriculum materials, but the classroom interactions were vastly different. One of the teachers was highly structured in his approach to high school chemistry. He laid everything out for the students in a step by step manner and all the students had to do was master the system. The second teacher was more unpredictable. His planning was more open ended and he applied fewer external constraints on students. These differences had their basis in the two teachers' beliefs about how students learn, what can be done to enhance student learning, and what constituted a good background in science. The beliefs teachers have about how students learn impact the teachers' pedagogical decisions. The teachers' beliefs about what would help students be more successful learners in the future influenced the teachers' classroom policy decisions. The beliefs teachers have about what constitutes a "good background" in chemistry effects the teachers' decision about what content to emphasize. It is also important to note that despite the differences in the two teachers, both were deemed effective teachers using a variety of descriptions of effective teaching found in the literature. These findings have implications for the current national search for a curriculum that will improve precollege science teaching and learning. Writing another new curriculum or establishing national goals for science education, without considering the power of the belief of individual teachers will bring about little change in the science classroom across the country. There are also implications for teacher education when one considers the power of a teacher's personal epistemologies and the fact that two very different teachers could both be effective.

CASE STUDIES AS REFLECTIONS OF SCIENCE AND MATHEMATICS TEACHERS' BELIEFS: THE UTILITY OF A NARRATIVE SYSTEM OF ANALYSIS

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Case studies, as research tools, are proving useful in capturing forms of cognition such as teacher belief. Teacher belief is often tacit and unconsciously held and cannot be inferred simply by observing the action of the teacher in the classroom. A variety of approaches have been used to infer underlying belief from teachers' narrative case studies. The central concern of this study was the search for a useful system of analysis that would evaluate science and mathematics teachers' written case studies based on theory and research concerning narrative model. Experienced science and mathematics teachers (n=24) wrote a minimum of four narratives: an open case, a closed case, a solution to a classmate's open case, and a response to a classmate's closed case. The link between teachers' pedagogical beliefs and written narratives was explored through interviews. Structural and content features of the case studies that were examined using this narrative approach revealed little about underlying teacher belief. Significant patterns emerged when narratives were examined on the basis of qualities that transcended the structure and content. The important themes that were evident included sensitivity to internal struggles catalyzed by a classroom problem, explicit moral and ethical concerns and a sense of history reflecting the feeling that the teacher in the case had lived with a problem over time.

REFERENTS FOR THOUGHT AND ACTIONS IN SCIENCE CLASSROOMS

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A problem that frequently is encountered is that teacher educators and curriculum designers expect teachers to change the science curriculum without first being aware of what is happening in schools and the reasons for what is happening. This study is premised on an assumption that teachers have good reason for doing what they do when they implement the science curriculum. Furthermore, if changes are to be made, it will be necessary for teachers to make sense of the intended changes and have a strong rationale to support change. Accordingly, a study was designed to investigate what happens in science classrooms from a cultural perspective. A three-year interpretive study of a high school science teacher and the culture in which he is teaching led to the formulation of a grounded theory with four components. 1) A personal epistemology does not necessarily act as a referent for a teachers' planning and implementing of a science curriculum. 2) Myths act as referents for the roles of teachers and students in science classes. Changes which violate myths are unlikely to be implemented into the classroom for any length of time since they will not make sense to the teacher or students. 3) Personal metonyms, beliefs, metaphors, and images can act as referents for teacher and student roles in a classroom. 4) The process of changing classroom roles necessitates a commitment for personal change, a vision of what the change curriculum will be like, and reflection on actions in relation to thoughts and vice versa. Two types of classroom behaviors can be distinguished: those that are a part of routines and those which are deliberative. In the case of behaviors which are deliberative, it is relatively straight forward for teachers to reflect on what happens and make adjustments. However, in the case of routines, it is necessary to de-construct each into its components. This process involves transforming routine practices into deliberative actions. The processes of de-construction, reflection, and change can take a long time to occur (as long as two years for some routines). The study has implications for the education of practicing teachers and formulation of policy with respect to the reform of the science curriculum,. Further research on the cultural dimensions of teaching and teacher change are warranted from a perspective of semiotics which incorporates analyses based on metonyms, idealized cognitive models, myths, beliefs, metaphors, and images.

IMPLEMENTING COOPERATIVE LEARNING IN HIGH SCHOOL CHEMISTRY CLASSES: A CASE STUDY OF PRACTICAL CHANGE

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This paper presents findings from a case study involving a science teacher who was committed to changing his practices. An interpretive study was planned to investigate the factors which determined how the teacher, who for sixteen years had taught chemistry in a traditional lecture format, incorporated cooperative learning into his high school chemistry curriculum. Data sources for this study included weekly interviews with the teacher over the 12 month course of the study as well as field notes from classroom observations conducted on a biweekly basis and audio-tape recordings of student/teacher interactions during group work. All the interviews were taped and later, transcribed for analysis. The analysis and interpretation process consisted of reviewing the data sources and formulating assertions. Efforts were made to refute assertions and special efforts were made to explain each piece of data that did not support an assertion. The assertions for which the amount of supporting evidence exceeded the amount of non-supporting evidence are presented. Teachers' practical knowledge is constructed on the basis of what happens in classrooms. Because all new knowledge is filtered through a framework of beliefs which the teacher already possesses and is adapted to fit those extant frameworks, simply suggesting changes in practices or providing another individual's model for practical change may not result in the desired outcomes. If teachers are to create and maintain changes in practices, they must reconstruct their knowledge frameworks relating to teaching and learning and how they may best be accomplished in their own classrooms. The findings of this study suggest that commitment to change and knowledge about the methods others use in implementing new practices are not sufficient to facilitate immediate, desired changes in science teaching. Through their experiences, science teachers may construct beliefs about the nature of science, how students learn, how science should be taught, and what is important for students to know about science which suggest implementation of conflicting teaching practices that subvert their intentions in implementing new practices. Furthermore teachers develop routines which they have learned to use automatically in order to make teaching a less complicated activity. Teachers may plan to implement practices, such as cooperative learning, intending to provide students with opportunities to experience science knowledge construction socially; but they may undermine the intent of such activities as they engage in routing practices. Furthermore this study suggests that implementation of cooperative learning takes time; time for teachers to experiment in their own classrooms, to reflect on what works and what doesn't work and why, and to construct knowledge about what teaching and learning in cooperative settings might be like.

FROM GALILEO TO PIAGET: HOW DO WE CONSTRUCT EPISTEMOLOGICAL THEORIES?

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The objective of this symposium is to study Galileo's method of idealization, by which he separates the ideal or scientific object of knowledge from real objects, and draw implications for the construction of epistemological theories for science education. The first member of the Symposium is a science educator (chemistry) whose research interests include the application of cognitive psychology to science teaching, with special emphasis on individual difference variables, such as information processing capacity and the perceptual field effect. The second member of the Symposium is a science educator (biology) whose research interests include the application of cognitive psychology to science teaching, with special emphasis on cognitive variables that predict achievement in science. The third member of the Symposium is a philosopher of science with major contributions towards an understanding of the importance of the epistemic subject in Piaget's genetic epistemology, and Galileo's methodology of idealization.

THE MEANING OF SCIENCE TO 8 TO 14 YEAR OLDS: DIFFERENTIATION AND DEVALUATION DURING THE THRESHOLD YEARS

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The purpose of this qualitative, interpretive study was to investigate the meaning and value of science to students in third through eighth grade in a small college town in the Northwest. The study's results were intended to be useful to the local school district in its efforts to maintain middle school pupils' interest in science, and also to provide insights relating to national survey results showing declines in pupil attitudes toward science during the upper elementary and middle school years. Data gathering techniques during the year-long study included both formal and informal interviews with 84 grade 3-8 pupils and twelve science teachers, as well as participant observation in multiple science classes at each of these grade levels. Patterns in the students' beliefs about the meaning and value of science were identified. Patterns of particular interest included: (1) consistency across grade levels in students' descriptions of the most effective methods for teaching and learning science, and agreement that the preferred methods were used more in the elementary grades; (2) the existence of social networks supportive of younger students' (grades 3-6) extracurricular science activities, along with the perception by older pupils (grades 7-8) that pursuing science leads to increased social isolation; (3) the inability of the older students, but not their younger counterparts, to identify ways that school science relates to everyday experience; and (4) the inability of students across grade levels to describe what a scientist's work involves in even minimal detail. This study describes these and other aspects of science's meaning to pupils during the threshold years preceding students' decisions about which academic or professional paths to pursue. The next step will be to consider classroom implications of findings in order to develop programs which stimulate and maintain pre-college pupils' commitment to science.

AFFECTIVE OUTCOMES ASSOCIATED WITH COOPERATIVE LEARNING IN AN UNDERGRADUATE PHYSICS COURSE FOR NON-SCIENCE MAJORS

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Described is a portion of the evaluation of a pilot course developed to teach physics to non-science majors at a major southwestern university, team-taught by a research physicist and a science educator. An important aspect in the first two semesters' development and evaluation of the course was the identification of effective instructional, laboratory and classroom management strategies that enhance cognitive and affective outcomes. This paper describes the affective outcomes associated with the incorporation of small-group cooperative learning in the second semester's pilot of the course as an additional strategy to improve students' attitudes towards the course, towards physics and towards themselves as problem solvers. At required weekly meetings, six groups of four to six students met to solve physics homework problems assigned during the lecture portion of the course. Each individual in the group was awarded a grade for the completion of a group solution to the problem. Log books from cooperative learning groups and graduate student monitors were used to acquire information about the attitudes of students towards the course, towards the cooperative learning experience, and towards themselves as problem solvers. Final student evaluations of the second semester's course were compared with the first semester pilot. An analysis of student and mentor logs and course evaluations revealed no positive changes in the attitudes of students toward physics, the course or towards their abilities to succeed in problem solving. All data pointed to extremely pervasive, consistent feelings of helplessness, low task persistence, and the rather typical "maladaptive motivational behavior patterns" characterized by Dweck (1986). These findings led to the subsequent development of an ameliorative intervention along social-cognitive lines for the next semester of the course that incorporated issues of self-confidence, goal orientation, and adaptive motivational behaviors into the small-group cooperative learning structure of the course.

THE RELATIONSHIPS BETWEEN TRACKING LEVELS AND TEACHER AND STUDENT PERCEPTIONS OF THEIR HIGH SCHOOL INTRODUCTORY SCIENCE COURSE QUALITY

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The primary purpose of this study was to determine whether or not there is a relationship between tracking levels and teacher/student perceptions of their high school introductory science course quality. Even though similar investigations using subjects from introductory science classes appears limited, other research suggests that students in lower track classes would have access to few instructional resources. Such discrepancies may be reflected by differences in perceptions of course quality when teachers and students of upper and lower tracks are compared. The sample consisted of 12 teachers and their 681 students from nine urban, suburban, and rural high schools in southeastern Michigan. All teachers selected taught both upper and lower level groups. The students, 82% in ninth or tenth grade, were enrolled in upper or lower level introductory general science, biology, earth science or physical science classes. Separate, but correlated, teacher and student questionnaires were designed to measure perceptions of science course quality. Respondents ranked each course quality perception item on both desirability and achievement levels. First, the respondent indicated the degree to which s/he believed the variable was desirable. Then, s/he evaluated the degree to which s/he perceived that the variable was actually being achieved. Responses were made on five-point Likert scales. In addition to the perceptions of science course quality questionnaires, the research included a 16-item "Attitude Toward School" (ATS) instrument developed by Akinmade (1982). Biased discriminant analysis, Hotelling's T2 and separate t-tests, teacher ratings of their upper and lower level classes did not differ significantly; however, there were significant variations between upper and lower level student scores: 1) Upper level students showed significantly higher overall ratings on several variables relative to both "desirability" and class "achievement" of the course quality indicators used in the study. 2) Scores on the ATS questionnaire were significantly higher in the upper level group. In general, teacher ratings were significantly higher than those of their students. There was no conclusive evidence to link possible differences in either perceptions of science course quality or attitude toward school with a particular demographic region or socioeconomic community status. Lowest "achievement" and "desirability" ratings given by both teachers and students related to use of computer technology in science education, and involvement of students in the design of experiments. Both teachers and students, however, rated "desirability" of these variables significantly higher than "achievement". Further research is needed to determine possible reasons for such perceptions. Regarding differences in student perceptions, while causality cannot be established from these research data, educators need to seriously consider possible reasons for the variations revealed. If "ability grouping" is deemed to be a significant factor, then research-based alternative teaching strategies may need to be explored.

ATTITUDES, BELIEFS, AND PERCEIVED NEEDS OF SCIENCE TEACHERS TOWARD THE USES OF COMPUTING TECHNOLOGIES

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In the last ten years, computing technologies and the uses of these technologies have increased in the public school setting. Approximately one-fourth of high school science teachers use computers; however, the pattern of computer use is low at all grade levels and in all subject areas. Previous surveys have shown that most science educational software in use is drill and practice, followed by tutorials, programming, and word processing. The objective of this study was to gather information about and assess the accessibility, use, and perceived needs toward computing technologies of middle school and high school science teachers in two large rural school districts. A questionnaire, Survey of Usages of Computing Technologies in Science and Mathematics Teaching, was designed and developed in accordance with the Ajzen and Fishbein theory of attitudinal assessment. Thirty middle school and high school teachers responded to the questionnaire (70% return). All respondents indicated that they used a computer and had basic competency skills when using the computer. More that one fourth of the teachers had access to a computer at home to assist in planning, forty percent had access to classroom computers with large projection screens, seventy percent had a separate computer lab, and fourteen percent had a computer area in class. Ninety percent received no courses on computers in science education during undergraduate or graduate school. More than fifty percent of the teachers indicated that they never or rarely used computers to calculate grades. To manage instruction, or to develop curricular materials. More than fifty percent of the teachers indicated that they never used computers to generate simulation data or to investigate a simulation. More than seventy percent indicated that they never used computers to conduct a scientific investigation or to use telecommunications. More than half of the teachers indicated that they never used computers to solve problems, to gather and analyze data, or to test knowledge of facts. In general, teachers felt the most important instructional uses of computers to be the practice of learned skills (36%), conducting a scientific investigation (33%), the testing of knowledge of facts (28%), and the simulating of science processes (27%). As more applications of computing technologies continue to emerge in science education, teachers need to develop their professional skills in employing this powerful medium to enhance their students' learning. Many studies in science, mathematics, and other areas have yielded evidence supporting arguments that the appropriate use of computing technologies can result in significant enhancements in student learning. The findings from this study supported the generalizations and trends reported in prior assessments of computer use by teachers.

THE EFFECTS OF MICROCOMPUTER-BASED LABORATORY EXERCISES ON ACHIEVEMENT AND ATTITUDE TOWARD PHYSICAL SCIENCE OF PRE-SERVICE MIDDLE SCHOOL TEACHERS

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The purpose of the study was to investigate the effects of microcomputer-based laboratories (MBL) on pre-service physical science teachers' academic achievement and attitudes toward physical science, computers, and the use of computers in science. Seventeen University of Georgia students enrolled in a physical science course for pre-service middle school teachers participated in the study. The content material covered was divided into two instructional units. Unit one lasted three weeks and covered the concepts of distance, velocity, and acceleration. Unit two lasted two weeks and covered heat and temperature. Quantitative data were collected using an attitude instrument and two achievement instruments. The attitude instrument contained subscales measuring attitude toward physical science, computers, and the use of computers in learning science. The attitude instrument was administered prior to the study and again at the end. Each achievement instrument covered a single instructional unit and was administered prior to the beginning of the unit and again at the units completion. Quantitative data were analyzed by calculating a t statistic. Qualitative data were obtained through interviews and observations. The following conclusions appear to be tenable based on achievement data, attitude data, and data obtained from interviews and observations: (1). MBL has a significant positive influence on students' achievement relative to motion ($p<.04$ on all subscales). heat, and temperature ($p=.003$) and a significant positive influence on students' attitudes toward the use of computers in learning science ($p=.02$). (2) MBL affects students confidence in interpreting physical relationships in science by providing a framework which allow students to refine their explanations and interpretations of concepts and by encouraging students to articulate and elaborate on their own personal conceptions. (3) Students have confidence in MBL as a problem solving tool since they do not feel the need to monitor the data collection process, they consider MBL as the final authority in resolving any conflicting opinions, and they considered MBL as a desirable alternative to the traditional laboratory exercises performed in physical science. (4) MBL provides students with a graphical representation of velocity as the rate of change of distance, provides them with the foundation for understanding instantaneous velocity, prepares them to sketch the distance and velocity graphs must be drawn with respect to some prespecified origin, and provides a visual representation of how an object can have a constant acceleration while its velocity is constantly changing. (5) Using MBL, students are easily convinced that temperature must remain constant when a phase change occurs and that temperature differentials must be considered when determining which of two objects requires more heat energy to maintain its temperature.

A MICROCOMPUTER BELIEFS INVENTORY FOR MIDDLE SCHOOL STUDENTS: SCALE DEVELOPMENT AND VALIDATION

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The Microcomputer Beliefs Inventory (MBI) was developed and validated to measure the self-efficacy and outcome expectancy beliefs of middle school students toward computers. Item analysis, scale reliability assessment, and factor analysis of scale integrity were conducted upon a sample of 269 sixth, seventh, and eighth grade students. Both scales performed with good reliability (Self-efficacy alpha = 0.90 and Outcome expectancy alpha = 0.85), and factor analysis clearly demonstrated the distinctiveness of the constructs measured. Preliminary evidence of the construct validity of both scales was clearly demonstrated by their predictable covariance with variables such as attitude toward computer, attitude toward science, interest in computer learning, interest in science learning, and expectations for computer learning. Also *t*-tests also revealed a strong relationship of the scales to computer access within the home. The MBI appears ready to utilize in future research efforts.

A PROFILE OF USERS OF A LEVEL ONE VIDEODISC-BASED ELEMENTARY SCHOOL SCIENCE PROGRAM

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A number of studies in science education have indicated the general effectiveness of level one videodisc based programs in improving student knowledge in the sciences. The purpose of the evaluation study was to ascertain the effectiveness of the videodisc-based elementary science program in selected fourth grade classrooms as determined by the users of the program involved in pilot testing. The study was conducted to: collect information about level one users' teaching experiences, their academic specializations and their level of experience with various forms of technology; describe classroom behaviors and perceptions of students and teachers and the ecology of the learning environment; determine teachers' attitudes toward technology and state anxiety toward teaching of science; describe the impact of the innovation on the needs and concerns of teachers; identify students' attitudes toward science/technology and interest in science outside the classroom; and identify students' science content knowledge and skill development base before and after the implementation of the videodisc-based science program. Student information was collected through the administration of interviews, assessment of science-related attitudes, skills and content, and classroom observations and administration of assessments of concerns and anxiety toward science and technology. The results indicate the following: the pilot teachers are experience, enthusiastic, and positive toward using the innovation and expressed a degree of hopefulness that the videodisc program would encourage interest in science and technology among their students; the majority of pilot teachers use the program supplemental to an existing elementary school science program; the students in the pilot classrooms demonstrated great interest in the videos that depicted motion and sound; the observations of classrooms indicated that most teachers employed the following instructional sequence: review/objectives, videodisc, discussion, videodisc, discussion, and culmination; while the pilot teachers initially exhibited a strong, positive attitude toward technology, their attitude continued to increase significantly at the culmination of the pilot testing.; while the pilot teachers initially exhibited low anxiety toward the teaching of science, their anxiety decreased significantly at the culmination of the pilot testing; initially the pilot teachers demonstrated a typical nonuser profile of an innovation. Upon the culmination of the pilot testing, a shift occurred in their concerns indicating a move from the less intense, self concerns to more intense concerns of the impact of the innovation on their students; initially all students demonstrated a positive attitude toward science and technology. Upon the culmination of the pilot testing, the total group and the male students showed a further increase in positive attitude toward technology; upon the completion of the pilot testing, all students, both males and females, showed an increase in gain scores on the science content and skill assessment.

IMPROVING CHEMISTRY ACHIEVEMENT THROUGH EMPHASIS ON THE PARTICLE NATURE OF MATTER

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Chemistry phenomena can be understood on three different levels: the sensory, the atomic/molecular, and the symbolic. Over the past 25 years, chemistry instruction has emphasized the symbolic level and recent studies indicate that students have little understanding of the atomic/molecular and sensory levels. The purpose for conducting this study was to determine whether an increased emphasis on the atomic/molecular level in an introductory chemistry course at the high school level would result in an increase in understanding at all three levels. It was hypothesized that this would be the case because teaching on the atomic/molecular level requires the use of phenomena (sensory level) and symbols. A second purpose of the study was to determine students' misconceptions at each level. The sample consisted of 66 high school chemistry students of one teacher in a consolidated school in the midwestern United States. Two classes (n=43) received the treatment which consisted of an increased emphasis on the particular nature of matter throughout the school year through the use of overhead transparencies, worksheets, and magnets representing particles. The control class (n=23) received regular chemistry instruction. Triads of multiple choice test items (one on each of the three levels) were embedded in the regular chemistry tests administered by the teacher throughout the school year. A total of 20 triads (60 questions) constituted the achievement measure which had a KR-20 reliability of 0.71. In addition to answering the multiple choice questions, student were asked to explain their selection of the correct answers and the nonselection of incorrect answers for randomly selected atomic/molecular questions. Three control and three treatment students were also interviewed at the end of the school year to determine misconceptions and how well students integrated the three levels in their thinking. The GALT test which was administered at the beginning of the year was used as a covariate in the analysis of variance to control for differences in ability in the three chemistry classes. Analysis of data indicated that there was a significant difference in achievement between the treatment and control groups at the 0.02 level favoring the students who had the increased emphasis on the particle nature of matter. An examination of the means on the three subtests indicated that the increase was evenly distributed across the three different levels of representing matter. These findings were supported by the open-ended responses on the individual test items and by the interviews. Although the difference in the means for the treatment and contrl of students was both statistically and educationally significant (10% increase) neither group scored particularly high on the measure (less thatn 50%) indicating that additional means must be taken in the teaching of high school chemistry to improve achievement.

A CROSS-AGE STUDY OF FIVE CHEMISTRY CONCEPTS

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The understandings and misunderstandings of 100 junior high, 100 high school, and 100 college students were examined in regard to five chemistry concepts. The students were all in the final stages of coursework in chemistry or physical science. The concepts addressed were: chemical change, dissolution of a solid in water, conservation of atoms, periodicity, and phase change. Differences in the amount of experience with the concepts (grade level) and reasoning ability were analyzed as possible sources of the variation in understanding. Results found both variables statistically significant for most concepts and the concept battery, but no interaction effect was observed. Tracing the number and types of misconceptions through grade levels reveals several interesting patterns and suggest possible sources of misconceptions.

STUDENT LEARNING IN BIOLOGY AND PHYSICS: THE EFFECTS OF STUDY STRATEGY AND LEARNING CONTEXT

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Recent reviews of the results of the research into students' conceptual scientific knowledge have suggested that future studies should go beyond identifying and describing students' conceptual knowledge, and focus more on the characteristics of student learning which are related to the development of better conceptual knowledge. In this paper we describe the results of research which has studied the relationship between students' propositional knowledge (as measured by concept mapping tasks) ad their study strategies (as measured by a student questionnaire) for students studying "electricity" and "photosynthesis" in first year university courses. The results show that, in general, deeper and more meaningful study strategies are associated with better propositional knowledge. They also show that, depending on context, prior knowledge has both a direct and an indirect impact on post knowledge. The indirect impact occurs as a result of the effect of prior knowledge on the adoption of study strategies.

THE CONSTRUCTION AND APPLICATION OF A COGNITIVE-NETWORK MODEL OF PREDICTION PROBLEM SOLVING

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Cognitive science research offers exciting hope for the development of innovative science teaching strategies that facilitate the development of optimally interconnected procedural and declarative knowledge networks. Improving students' neural networks should improve their abilities to think critically, reason logically, learn more efficiently, and solve more complex problems. Before this auspicious vision of the future can become a reality, the structure, composition, organization, and function of students' knowledge networks must be understood in great detail. The primary purpose of this research study was to reveal the intricacies of students' knowledge networks by constructing a cognitive network model associated with one particularly important problem-solving skill - prediction. The central role of prediction in learning, problem solving, and scientific progress demands that its cognitive mechanisms be investigated and that teaching and learning strategies be developed with prediction as the focus. Fourteen prediction problem sheets, involving six different conceptual systems in biology and three different problem formats were administered to pre-service college students in two science-teaching methods classes. Each problem sheet required students to make a prediction, either in writing or on a graph, and then to explain their reasoning in writing. Twelve students from each class solved the problems silently. An additional four students from each class solved the problems via video-taped think-aloud interviews. Qualitative data analysis followed a series of four steps, with each step building from the previous step: 1) identification of cognitive behavioral categories associated with successful and unsuccessful predictors, 2) construction of sequential behavioral transcripts of both successful and unsuccessful predictors, 3) identification of cognitive scripts for successful and unsuccessful predictors with attention to procedural and declarative knowledge, and 4) development of a cognitive-network model of prediction problem solving. Successful subjects identified and applied scientifically correct terms, variables, and causal relationships that were directly relevant to the prediction problem. Silently administered prediction sheet were not as effective as think-aloud interviews for identifying knowledge bases of individual students, but revealed considerable information about the conceptions of each class as a whole. The cognitive network-model constructed by this research depicts prediction problem solving as an intricate interweaving of appropriate procedural knowledge that connects, manipulates, and transforms relevant declarative knowledge. The model implies conceptual understanding to be dominated by declarative based cause-effect relationships and the basic driving mechanism of thought, especially for prediction, to be cause-effect reasoning. An Explicit Prediction Teaching Strategy (EXPRTS), developed from the model, encourages students to build a predictive framework of successful cognitive scripts. Improving prediction problem-solving skills for science students can lead them toward a greater understanding, application, and appreciation of the scientific process.

ENHANCING HIGHER ORDER THINKING SKILLS IN SCIENCE EDUCATION

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The effects of different teaching processes on students' lower and higher mental process achievement were investigated. Three variables in teaching higher mental processes were examined: teachers' questions, feedback-correctives, and instructional materials. Ninety eight seventh grade science students were randomly assigned to one of four conditions. One control and three experimental groups were compared. The control condition approximated conventional instruction where the teacher taught the courses as usual. The procedures used were those found in many classrooms typically involving the teachers' use of predominately lower cognitive classroom questions as well as instructional materials consisting of mostly lower cognitive tasks. In one experimental group, the minimal opportunity to learn higher mental processes, teachers asked at least one-third higher cognitive classroom questions and used the same instructional materials as the teachers in the control condition. In another experimental group, the intermediate opportunity to learn HMP, a mastery learning feedback-corrective procedure was employed which had at least one-third higher mental process questions and instructional materials were used which included at least one-third higher cognitive problems, illustrations, and tasks. In this condition, teachers' classroom questions were predominantly at the lower cognitive level. In the final experimental group, the maximal opportunity or learn HMP, at least one-third of teachers questions emphasized HMP; feedback-corrective procedures included at least one-third higher cognitive material and instructional materials also included at least one-third higher cognitive problems and task. The hypothesis that student achievement is a function of the degree to which the teaching processes employed by a teacher provide adequate opportunities to learn higher mental processes was supported. Most striking and surprising was that as more time and emphasis was put on teaching the higher mental processes, it was fount that with each gain on the higher mental process there was a corresponding gain on the lower mental processes. One important implication is that improving HMP is not at the expense of LMP. It is believed that the process of solving HMP problems and tasks requires the student to become more actively involved in learning which in turn creates interest, enthusiasm, and excitement: HMP teaching makes learning come alive. The methods developed in this study may be of particular interest of schools since implementation should be relatively easy and not costly. Increasing emphasis on higher mental process instruction resulted not only in increases in higher mental process achievement but also in very similar increases in lower mental process achievement.

THE EFFECT OF APPLYING STRUCTURED-SCIENTIFIC-ENQUIRY (SSE) INSTRUCTION MODEL IN THE GIFTED EDUCATION

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This Study is conducted to find: 1) whether the gifted pupils like to receive the SSE Model; 2) whether the gifted pupils are capable of comprehending the content of the model; 3) whether the SSE Model is an effective one, when comparing with the controlled group A which received Suchman's Inquiry Training and the controlled group B which received no treatment other than the school curriculum. Opinion survey and experiment method are adopted to test the hypothesis concerned. There are 156 gifted pupils, grades 5 and 6, take part in this study. With the MANOVA and MANOCOVAT techniques, the main findings are as follows: 1) 90% of the SSE group felt the model interesting; 2) 94% of the SSE group felt the content of the model easy, or not to difficult; 3) When the experiment treatment was over, the scores gained by the SEE group and the controlled group A were compared. SSE group was found to get higher score in "Logic Structure" sub-test, but not in the "Identifying-Variable" and "Giving-Operational-Definition" sub-tests. Comparing the SSE group and the controlled group B, SSE group got consistently higher scores than the 3 sub-tests mentioned above. (P<.05) 4) As for the five aspects of the test "Scientific Nature Comprehension" there are no differences between the SSE group and the controlled group A. But there are differences between SSE group and the controlled group B. (P<.05). To sum up, the SSE Model is a promising candidate in enriching the curriculum of the gifted education.

DEVELOPMENT OF CREATIVE THINKING AND INVENTIVENESS: SOME RECENT APPROACHES

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The U.S. is losing its edge in innovation and invention. Too often overlooked is the integral fact that new ideas cannot come from dollars or bandaid political promotions, but from the imaginative minds of people. The Cognitive Spiral Model of Cognitive Processing attempts to delineate the sequence of mental processing that occurs during creative thinking episodes. This understanding can then be used as a basis for instructional design. The model postulates five component processes that occur in a specific sequence and in a spiraling manner that accounts for the change in the knowledge base held in the long-term memory. Researchers have provided some evidence that specific attention to involvement of students in multiple experiences with creative thinking as suggested by the Cognitive Spiral Model can result in enhanced cognitive functioning abilities of both middle level students and their teachers. In one study, an Inventiveness Training Program (ITP) was developed. The program consists of "hands-on" and "minds-on" activities focusing on visual thinking, humor, brainstorming, alternate uses of common objects, discrepant events, and inventions built from junk and available inexpensive materials. "Imagineering " lessons are a major feature of the program, in which oddball "inventions" with accompanying fanciful storylines are presented by teachers. Students are challenged to draw "blueprints" or build working models of how various inventions might work. A pretest/posttest comparison group study showed the ITP students were more inventive, scored higher on a test of creative thinking, and were more positive towards science than their non-ITP peers. In a related study, middle level science teachers were involved in a 9 month program designed to both improve their personal creative thinking abilities and develop their skills in teaching inventiveness skills to students. Measures from an invention evaluation instrument and the Purdue Creativity Test found significant improvements in the targeted skills of participants. Results of these studies provide evidence that: 1) training programs can enhance the creative thinking and inventiveness of both middle level teachers and their students; 2) middle level science teachers can learn to successfully develop creative thinking and inventiveness in their pupils; 3) many middle level students have remarkable abilities to invent simple devices to solve problems of everyday life; 4) creative thinking/inventiveness programs can improve middle level students' overall attitudes toward school science; 5) female students tend to benefit even more that male students from these programs. Application of certain creative development techniques seem to be effective in promoting the sense of wonder and skills of creative thinking of both children and their adult mentors.

A FIELD TEST AND EVALUATION OF A NEW TOOL FOR QUALITATIVE RESEARCH IN COMPUTER ASSISTED INSTRUCTION

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A short qualitative study of preservice elementary teachers' first interactions with a HyperCard stack was completed, during which a new software package was evaluated as a tool for qualitative studies in the area of computer assisted instruction (CAI). The students were observed remotely via a network, and observation were triangulated with data collected via the more conventional means of audio and video recording, and programming built into the instructional stack. Results showed a mostly positive response of the students to the HyperCard stack, although the students followed very different patterns through the instructional stack. The researchers highly recommended the networking software as an additional qualitative research tool.

VARIABLES INFLUENCING THE MEANING OF LABELS IN QUALITATIVE RESEARCH

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The purpose of this study was to identify the variables which influence the meanings of labels used by science education researchers doing qualitative research. This was a qualitative emergent design study in which participant observation, informal interviews, and document review were used to gather and analyze data in recurring cycles. Presentations and discussions among qualitative researchers at NARST conferences and JRST articles were the primary data sources. Secondary data sources included qualitative research methodology articles from other areas of education, philosophy, and the social sciences. The glossaries generated from the meetings and the readings were constantly compared for clues to relationships among the ways various authors used labels and for the variable influencing the way the labels were used. The concept of a research tradition played a dominant role in developing the emergent model. A significant variable which influenced the meanings of labels in science education was that individual science education researchers adopted or adapted different research approaches used in a wide variety of other disciplines, especially philosophy and the social sciences. Within each of the disciplines from which science educators derive guidance, there was great variety in the way scholars in each discipline used their own labels. In addition, there were a variety of qualitative research traditions used in each discipline. The societal paradigm shift to a new world view is contributing to the multiple meanings of labels. A person's world view is the context which influences the attributes he/she ascribes to a word used a label to convey a concept. The new paradigm, is a new lens influencing what we see. Words we have used to describe and explain the world as we have known it under one lens take on new meaning when viewed under this new lens, adding to the plethora of interpretations of labels in qualitative research. A theoretical model of variable which influence the meanings science education researchers construct for labels in qualitative research emerged and consists of the: 1) pluralistic nature of qualitative research, 2) research traditions from philosophy and the social sciences, 3) societal paradigm shift and its impact, 4) debate between quantitative and qualitative researchers, and 5) multiple applications of qualitative research in science education. The model suggested the criteria for acceptance of the meaning of a label be the label's congruence with the context of the tradition in which it is used rather that its consistence with an isolated definition. Enhanced communication, then, does not come about by generalizing meanings of labels or arbitrarily, alone or collectively, setting absolute parameters on labels. It occurs because science education researchers familiarize themselves with a broad range of qualitative research traditions in use world wide, and accept the productive tension needed to foster creativity between keeping an open-mind and maintaining a standard. The multiple meanings of labels used in science education research can be viewed as an advantage rather than as a problem.

A STUDY OF SCIENCE TEACHING EFFICACY USING QUALITATIVE AND QUANTITATIVE RESEARCH METHODS

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Recent research on self-efficacy has emerged from the social psychology field with potential for explaining some of the phenomena observed in science education including avoidance of teaching science, reliance on the textbook, lecture styles of teaching, and lack of time given to science instruction. In education, efficacy has generally been defined as the belief that one's ability can bring about positive changes in students' behaviors and achievement levels. Research on efficacy in science education suggests that high efficacious teachers are more likely to use open-ended, inquiry, teaching strategies while teachers with a low sense of efficacy are more likely to use teacher directed teaching strategies such as lecture and reading from the text. The purpose of this study was to explore the validity of a quantitative science teaching efficacy instrument by comparing scores on the Likert Instrument with qualitative measures of teaching success. Teachers' rating of success on lessons taught and their explanation for their perception of success or failure were compared with their science teachers efficacy scores. The efficacy score on the Likert scale was also compared with teaching strategies chosen and the reasons for choosing the teaching strategies. Over two hundred preservice elementary teachers enrolled in required science methods classes participated in this study. These teachers answered questions of a 30 item Likert scale that measured teacher beliefs about ability to teach science to students in spite of all other factors such as home environment, school climate, and economical conditions of the school. These teachers taught a minimum of five science lessons and completed a journal entry after each lesson. The teachers' journals were studied by three different researchers using ethonographic research methods. Conclusions formed from the analysis of the ethonographic data were compared to the Science Teaching Efficacy Scores of the teachers. Preliminary analyses of this data show four things: 1) There appears to be a relationship between the efficacy score obtained on the Likert Scale and the teacher's rating of success of actual lessons taught; 2) Highly efficacious teachers more often report that the lesson was successful (or unsuccessful) because of things related to their own skill and student learning; 3) Teachers with a low sense of efficacy often report that the lesson was successful (or unsuccessful) because of things about the environment (things outside their own control) and comments by significant others; 4) The relationship between the teachers' level of efficacy and the instructional strategies they choice to use is inconclusive. There is not a clear pattern between the level of efficacy and types of strategies used to teach elementary science.

THE EFFECT OF DIFFERENT TEACHING STRATEGIES ON PRESERVICE ELEMENTARY TEACHERS PHYSICAL SCIENCE MISCONCEPTIONS

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Among the most important things students bring to science classes are their concepts. Educators use the term "misconception" to describe an unaccepted interpretation of a concept by the learner. Information and experiences the learner brings to the classroom have a direct effect on student learning. Because science is a discipline that builds on previous knowledge, the elementary school plays a fundamental role in science education. Researchers indicated that the science background of most inservice teachers and preservice elementary teachers are weak. Therefore, we need teaching training strategies that alter preservice teachers science misconceptions and at the same time serve as models for later use with their students. This study identifies preservice teachers misconceptions and tests two strategies designed to alter misconceptions. This uses a pretest and posttest research design. The sample consists of thirty eight preservice elementary teachers and all of them were administered the Physical Science Misconception Test (PSMT) at the beginning and end of the study. Subjects were assigned to three groups, two experimental groups and a control group. One treatment employs the teaching strategies associated with the Generative Learning Model (Cosgrove & Osborne, 1985). The other treatment follows the instructional strategies outlined in the Learning Cycle (Lawson, Abraham, & Renner, 1989). Results of the pretest indicate that this sampling of preservice teachers share a number of physical science misconceptions. However, little research is available indicating whether older learners have difficulty in abandoning their misconceptions, because formal reasoning skills are necessary to overcome prior misconceptions. However, little research is available indicating whether older learners have difficulty in abandoning their misconceptions. Because formal reasoning skills are necessary to overcome prior misconceptions, most preservice teachers would be expected to be formal thinkers and they may be willing to abandon misconceptions under the right circumstances. The results of this study should provide implications for researchers and teachers interested in identifying and altering students' science misconceptions.

THE DESIGN AND VALIDATION OF AN INSTRUMENT TO IDENTIFY PRESERVICE ELEMENTARY TEACHERS' INTUITIVE AND SCHOOL KNOWLEDGE OF THE CONCEPTS OF SURFACE AREA/VOLUME AND STATES OF MATTER

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In order to take into account in a more productive effective manner children's prior science knowledge in the development of science curricula and in the teaching of science, it is important for us "to know how to explore it, to know about its nature, and to consider the various ways [it] may, or may not, be modified" (Gilbert, Osborne, & Fensham, 1982). Given that many elementary teachers report feeling either ill-prepared or unqualified to teach science, the experience of this group of students in learning science particularly warrants continued investigation. This study attempts to take a step beyond identification of preservice elementary teachers' science misconceptions in the direction of concurrent characterization of the bases of these ideas. Using a multi-step process of development, revision and validation, an eleven item multiple-choice test exploring the concepts of surface area/volume and states of matter was developed for subsequent use in evaluating and revising a science process skills course for preservice elementary teachers. Each of the items in the test included a description of a situation, a multiple choice question based on the situation followed by eight to twenty possible explanations for the answer selected. The explanation included correct, incorrect and intuitive and school knowledge items. Test results allow the researcher to identify pre-knowledge about the concepts of interest and to characterize the degree of congruence between the learner's "school" and "intuitive" sources of knowledge. Reliability of the SVSM Concept Test determined for preservice elementary students was 0.94 (Cronbach's alpha). It is proposed that this and similar concept tests could be used in evaluating the effectiveness of strategies devised to change misconceptions or to bring learners' school and intuitive knowledge into congruence; in conjunction with other measures in evaluating conceptual change; and with other measures of ability or pre-knowledge to explore interactions with different methods of instruction.

ATTEMPTS AT SENSE-MAKING: PRESERVICE SECONDARY SCIENCE TEACHERS EXPLANATIONS OF SCIENTIFIC PHENOMENA

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This study was designed to determine preservice secondary science teachers' ability to explain common scientific phenomena that are a part of the usual school science curriculum and that are similar to the questions secondary school students frequently ask of their teachers. One hundred twenty five subjects in the study were candidates for secondary science teaching degrees at a large university in the United States. All were nearing completion of majors in science and were enrolled in a course in methods of teaching secondary school science prior to student teaching. Subjects were presented with a set of four observed events that required application of scientific knowledge to analyze and explain each. The events presented to students were: (1) free fall of lead and aluminum spheres of equal diameter, (2) cold water heating to boiling in an electric pot, (3) treatment of a tooth infection with an antibiotic and coincident diarrhea, and (4) warnings on television during the Thanksgiving - Christmas holiday season about the need to store cooked turkey in the refrigerator. In each case, a written problem was presented and subjects were asked to write explanations individually as a part of a series of classroom exercises during their methods course that focused on organizing scientific knowledge for teaching. Students' responses were collected and analyzed to determine the degree to which they conformed to propositional knowledge statements about each event formulated by a team of scientists and science educators. Results showed that while most preservice teachers in this study possessed a high degree of specific knowledge about each of the events included in the study, much of their knowledge was poorly integrated, and they had difficulty applying their knowledge in ways that resulted in clear, logically sound explanations. While these preservice teachers possess a strong background in formal science learning in their major field of study, and in supporting fields such as physics, most were ineffective in developing logically sound explanations and many held erroneous conceptions. Similar deficiencies in integration and understanding of scientific knowledge were recorded on the other topics; there are described in detail in the paper. While most people agree that a strong academic background in science is an essential requisite for secondary science teachers, this study shows that academic science background alone is insufficient. Prospective science teachers need opportunities as part of the formal science curriculum to integrate and apply their knowledge so that they are able to formulate representations and explanations of it that are logically sound and comprehensible by their future students.

EARLY PROBLEM SOLVING STAGES OF SUBJECTS INTERACTING WITH A GENETICS COMPUTER SIMULATION

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Previous learning studies and needs assessments in science education have provided evidence for the need for more intensive research in biology education in general, and genetics learning, in particular. One medium through which subjects' problem solving strategies can be examined through dynamic interaction involves the use of computer simulations. The use of a genetics computer simulation, Kangasaurus, enabled subjects to set up a particular genetic system (such as sex linkage) with which to demonstrate conceptual knowledge and to solve common problems. This study examined how learners engage in computer-based problem solving with a genetics computer simulation and focused on the decision which subjects made in early stages of problem solving. Using a think aloud protocol in conjunction with videotape recordings, each subject's commentaries and interaction with the simulation were recorded. The principal objective of this study was to examine, extract, and analyze common and unique problem solving characteristics and patterns of subjects who were expected to perform successfully when solving genetics problems. The five subjects who participated in this study held an undergraduate major in biology and completed graduate level courses in science, principally biology. The stages of problem solving extracted from verbal patterns of subjects and the computer monitor screen recording included: identifying the problem, representing the problem, reformulating the problem, planning the strategies, implementing the strategies, evaluating the strategies, and evaluating the solution in the context of the entire problem. Most subjects exhibited reflective problem solving behaviors (reflecting on the problem, the strategy, the solution, or the implementation of the strategy) concurrently with the other problem solving stages. All subjects were able to articulate the concept of sex linkage and relate it to the condition of either the male or female parents. In addition, all subjects were able to recognize critical cues which signaled a specific type of inheritance pattern (in this case, sex linkage). However, they exhibited difficulty when asked to demonstrate their understanding of sex linkage. Subjects either misunderstood how sex linkage related to the problem or how the role of probability and selection of parental genotypes in their genetic model was consistent with the problem. This research study provided rich information about cognitive processes of learners engaged with genetics problem solving and instructional software. Additional naturalistic and experimental studies are needed to better understand learning and instruction in science and to develop learning models and appropriate instructional strategies.

A BREACH IN THE RELATIONSHIP BETWEEN CORRECTNESS AND SCIENTIFIC CONCEPTUAL KNOWLEDGE FOR THE MEANINGFUL SOLVING OF A PROBLEM ABOUT OSMOSIS

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In contract with the meaningless execution of prescribed algorithms, meaningful problem solving has been valued as a desired outcome of science instruction. However, the findings of this study show that meaningful solving courses can generate correct solutions from ascientific conceptual knowledge. In this study, solvers meaningfully solved a graphing problem about osmosis. They generated solutions that conformed in every respect to the model graph, yet they had misconstrued the problem as being about air pressure. The link between a solver's scientific conceptual knowledge and the correctness of the solution was breached. The purpose of this report is to identify one condition of meaningful problem solving associated with this breach in the relationship between scientific conceptual knowledge and correctness. The solvers for this qualitative study were 14 upper division high school students and were efficient science learners and they were outstanding in their scientific conceptual knowledge and problem solving experience. Nevertheless, they were novices and were unfamiliar with the particular problem. The specification of novices obviated prescribed algorithms in an attempt to ensure a meaningful solving course. The specification of upper division high school students who had studied biology and were efficient science learners enhanced the likelihood for the solving of the unfamiliar problems. A problem about osmosis was selected because osmosis is a difficult topic. The solvers generated clinical interviews, think-aloud protocols, retrospective reports, and pencil-and-paper solutions. These were used to assess whether (a) a solving course was meaningful, (b) the conceptual knowledge was scientific, (c) the solver was a novice, (d) the solution was correct. A solving course was judged to be meaningful if the think-aloud protocol and retrospective report displayed a sensible series of inferences justifiable by conceptual knowledge. The conceptual knowledge was judged to be scientific if data from the clinical interview, think-aloud protocol, and retrospective report indicated that the solving course was embedded in an essentially accurate osmotic representation. The solver was judged to be a novice if he reported having no recollection of having tried to solve the problem or an isomorph. The solution was assessed as correct if it conformed with selected attributes of the model graph and if the intended meaning seemed to correspond with the apparent meaning. Thirteen of the 14 solving courses were meaningful. Four of the 13 meaningful solving courses generated correct solutions. Yet, two of the four correct solutions were embedded in ascientific conceptual knowledge about air pressure. These breaches between correctness of the solution and the solver's scientific conceptual knowledge were attributed to the standard nature of the solution to the problem. For the meaningful solving of a problem that involves graphing, it behooves those who assume that a correct solution indicates scientific conceptual knowledge to secure the relationship with problems having distinctive rather than standard solutions.

THE EFFECT OF THE CONSISTENT USE OF GENERAL PROBLEM SOLVING STRATEGY ON PHYSICS KNOWLEDGE ORGANIZATION

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In order to investigate the relationship between novice students' organization of physics knowledge and their use of general strategy for solving complex physics problems, we examined students' knowledge structure using a problem sorting task. The 28 students, selected from a class of 101 non-physics majors, had just completed a two quarter introductory physics course in which they received explicit instruction in the use of general problem solving strategy as well as instruction in physics content. Fourteen students (7 women and 7 men), judged to be strategy users, and sixteen students (5 women and 11 men), judged to be strategy non-users, completed a problem categorization task. In addition, representing experts as a comparison group, six advanced physics graduate students completed the tasks as well. Each students was asked first to organize 28 physics problems into groups based on similarities in perceived solution. Subsequently, each student was asked to construct subordinate and later superordinate categories for the problems following the same instruction. The results of the categorization task were analyzed for content and degree of hierarchical structure. Our results lead to conclusions in two areas. In the first place, our results corroborate and extend the conclusions from previous studies or problem categorization: novices more so than experts categorized on the basis of surface features of a problem rather than on its deep structure. However, our results show that novices exhibit considerable variation in this area, e.g. some novices use expert-like categories referring to deep structure, some novices strictly use a surface feature categorization scheme, most students use a mixture of surface features and deep structure. Furthermore, most students exhibit an ability to construct subordinate and superordinate problem categories. Most students, therefore, reveal some degree of hierarchical knowledge organization. Secondly, in response to our original question, we found that there is a relationship between a novice's knowledge organization and the novice's use of a general problem solving strategy. However, the relationship is subtle rather than dramatic. Among users of the general strategy construct fewer categories based on information explicitly given in the problem statement. Thus, taken as a group, novice users of the general problem solving strategy exhibit a more expert-like organization of physics knowledge than do novices who do not use the general strategy in problem solving.

INCORPORATION OF CRITICAL THINKING WITHIN A REGULAR HIGH SCHOOL BIOLOGY CURRICULUM

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The study describes the rationale and activities of a newly established project - the Biology Critical Thinking (BCT) project. The development of critical thinking has been regarded since ancient times as one of the major aims of education. One way and perhaps the most promising one is to infuse critical thinking activities within the regular school curriculum. Research has found time and again that students often fail in tasks which require critical thinking regardless of the nature and orientation of the curriculum they have studied. Like with other important skills deliberate efforts are needed to develop the skill and the habit of using it in different contexts (transfer). Four guidelines underline the BCT project: integration with the regular formal curriculum, repeated use under different circumstances and in a variety of context, explicit discussion of the metacognitive procedures employed, and time economy in order that other instructional goals will not be deprived. The pilot study reported here focusses on 10 skills such as drawing valid conclusions, refraining from overgeneralization, identifying assumptions, controlling variables and appraising advertisement. Seventy-seven 9th grade students participated. They were divided into four groups, two of which studied the regular curriculum, whereas, the other two studied the same curriculum enriched by BCT activities. These materials are described in the paper. Achievement was assessed by administering the Cornell Critical Thinking Test Form Z and a Critical Thinking Application Test (CAT) developed by the authors. Results revealed significant and substantial superiority to the BCT students. More details, discussion of the results and implications are presented in the paper.

THE EFFECT OF AN INTEGRATED CONTENT AND PROCESS SCIENCE METHODS COURSE ON PRESERVICE TEACHERS' ORIENTATION TOWARD TEACHING ELEMENTARY SCIENCE

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Among the frequently cited reasons for qualitative and quantitative deficits in elementary science programs are a lack of adequate science content knowledge (Victor, 1962), and poor attitudes toward teaching science. Duschl (1980) investigated how the disparity between science content courses stressing knowledge and methods courses dealing with the process of science add to the confusion and apprehension expressed by elementary education majors and evidenced by their general lack of confidence and anxiety about teaching science. Such negative experiences impact preservice teachers' attitudes. A modified approach to science content courses has direct implications for how elementary science methods courses may be modified through the integration of core science concepts within a process-oriented, hands-on science activity approach to facilitate teacher mastery of science concepts and improved attitudes and aspirations toward elementary science teaching. Within the revised methods course which served as the treatment effect in the present study, science concepts were embedded through use of a technology-based instructional tool which provided teachers with a structure by which to organize their science knowledge. In doing so, preservice teachers were introduced to the instructional relationship between conceptual knowledge and process-skill integration as a methodology of improved learning in science. With this in mind, the present study investigated the effect of an innovative instructional approach to an elementary science methods course which embedded core concepts with process skills development on preservice teachers' attitude and aspirations toward science teaching. The specific questions addressed by the study were: (1) Can a more appropriate instructional approach which integrated core science concepts with a process orientation be accomplished within a single methods course? (2) What are the applied effects of this instructional approach on preservice teachers mastery of core concepts? (3) What are the applied effects of this instructional approach on expressed teacher attitudes toward teaching science (i.e., attitude, aspirations, anxiety, and internal locus of control)? Preservice teachers enrolled in two sections of an elementary science methods course followed by the same syllabus but differed in how they utilized the time in the course during which science knowledge was addressed. The control class explored a variety of science concepts in conjunction with hands-on science process activities. The experimental group focused upon mastery of physical science core concepts taught through videodisc-based portions of an instructional program, Core Concepts in Earth Science, (Hofmiester, 1989), in conjunction with hands-on process oriented science activities. The results of the present study parallel those of Benson & Yeany (1986), Stefanich & Kelsey (1989) and Romance & Vitale (1989) who found that increased knowledge and understanding in science improved preservice teachers achievement in science as well as affective measures relative to the teaching of science.

RESTRUCTURING COLLEGE SCIENCE COURSES FOR ELEMENTARY PRESERVICE TEACHERS: SOME RESEARCH FINDINGS

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The purpose of this study was to evaluate the effects of "Our Water Resources", which is a new course - one part of a three year NSF supported preservice elementary teacher education program called P.R.I.S.E. (The Project to Improve Science Education). This is a project for the improvement of science instruction in the elementary classroom, through the development of a special science program for perspective elementary teachers. The objectives of the new science course are to enable students to: develop knowledge of science processes, of scientific instrumentation, and analytical procedures; to develop an interest in and confidence and competence with science; and to learn and understand concepts of biology, chemistry, geology and physics. "Our Water Resources" is a hands-on study of the region's water resources, emphasizing an investigative approach, in which participants function as scientists and under the guidance of the instructor, collect, analyze and interpret data. The purpose of this descriptive study was to evaluate the effects of "Our Water Resources" on preservice elementary teachers' (i) process skills, using TIPS II; (ii) attitudes towards the environment, using Horsley's Attitude on Issues of the Physical Environment; (iii) attitudes to science, using Motz Science and Scientists Attitude Inventory and; (iv) anxiety towards teaching science, using the State-Trait Anxiety Inventory. Nineteen elementary education majors in their freshman year at the Grand Valley State University were subjects for this study. Of these 14 were females and 5 were males. All the instruments were administered at the beginning of the Fall semester in 1989. The State-Trait Inventory was administered on the first day of class. The Motz Attitude Scale, the Horsely Attitude to Issues of the Physical Environment and the TIPS II were administered again in December. Due to the small sample size and the lack of control of extraneous variables, it is not possible to make any final conclusions or strong generalizations. However, the evidence does indicate that the students' experience with the first course in the PRISE curriculum has contributed to changes in the attitudes and knowledge of process skills. There has been a significant positive change in the students' attitudes toward scientists. Experiences with the PRISE curriculum had also fostered a positive orientation towards the environment. There was also a significant increase in the mean scores on the Test of Integrated Process Skills. This increase is an indication that "Our Water Resources" objective of "developing knowledge of science processes" is being met. The water resources course is now serving as a model for revising and restructuring the other courses in the PRISE project. The students are also identified and follow up data is being collected as they progress through the program.

TEACHING A HYPOTHESIS TESTING STRATEGY TO PROSPECTIVE TEACHERS

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Science teachers tend to focus on schema rather than underlying structures with greater explanatory power. One such structure is the recognition that the logical statement of implication can only be falsified. After instruction with a modified version of the four-card hypothesis testing task, pre-service elementary teachers were significantly more able to interpret logical statements, and falsifiers were more successful than verifiers. This study demonstrates that appropriate instruction can lead pre-service teachers to understand the process of hypothesis and falsification that is the procedure of theory testing in science.

THE INFLUENCE OF HANDS-ON SCIENCE PROCESS SKILLS TRAINING ON PRESERVICE ELEMENTARY TEACHERS' CONCERNS AND ANXIETY ABOUT TEACHING HANDS-ON SCIENCE ACTIVITIES IN TAIWAN, R.O.C.

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The purpose of this study was to identify whether the strategy of using hands-on science process skills training in an elementary science methods course was effective in: (1) reducing preservice elementary teachers' anxiety about teaching hands-on science activities, and (2) improving preservice elementary teachers' concerns about teaching hands-on science activities from concerns about "self" to concerns about "task" and the "impact" of hands-on science on children. A nonequivalent control-group quasi-experimental design was utilized in this study. One independent variable, the method of hands-on science process skills training, was investigated in this study. There were two dependent variables measured in this study: (1) the state-anxiety about teaching hands-on science activities to children, and (2) the stages of concern profiles about teaching hands-on science activities to children. Two measurement instruments [Stages of Concern Questionnaire (SoCQ) and State-Trait Anxiety Inventory (STAI) Form Y-1] were used in this study. Two instruments used in this study were translated into Chinese by the researcher. The sample under study consisted of 105 preservice elementary teachers enrolled in four sections of a science methods course at Taiwan Provincial Taichung Teachers' College, Republic of China. The experimental group (n=54) received regular class lectures without hands-on science activities. Analysis of covariance (ANCOVA) was used as the data analysis procedure. The results indicated that hands-on science process training was significant (P < .05) in reducing preservice elementary teachers' anxiety about teaching hands-on science activities and improving preservice elementary teachers' concerns about the "impact" of teaching hands-on activities to children. However, preservice elementary teachers' concerns about "self" fails to show a decrease in the experimental groups.

AN ANALYSIS OF THE RELATIONSHIP BETWEEN STUDENT-INVENTED HYPOTHESIS TESTING AND DEVELOPMENT OF REFLECTIVE THINKING STRATEGIES

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The present study was designed to test the hypothesis that a descriptive-type learning cycle (See Lawson, Abraham, & Reener, 1989) is insufficient to stimulate students to reason at a reflective level or to develop an understanding of, and facility with, the processes of scientific investigation. A learning cycle format designed to allow students to experience a concept at a descriptive level and to explore that concept through the generation of, and testing of, alternative hypotheses should (a) positively impact student understanding of the reasoning and processes inherent in science and (b) enhance intellectual development. In order to test the hypothesis, students in a ninth grade physical science course participated in descriptive-type exploration activities and an ensuing invention discussion. The expansion phases of the learning cycles were then varied from being strictly descriptive (control group) to providing students in one experimental group opportunity to generate and test hypotheses about phenomena related to the main concept of the investigation. A second experimental group designed experiments to answer a question posed by the teacher. The effects of the treatment were assessed through a pretest - posttest use of Lawson's Seven Logic Tasks, The Test of Integrated Process Skills (I and II), Lawson's revised Classroom Test of Scientific Reasoning, and a questionnaire generated and validated by the research team. A post-posttest three weeks after completion of the final investigation included Lawson's Seven Logic Tasks and The Test of Integrated Process Skills (I). The data have not been sufficiently analyzed to generate a results section at this time. However, preliminary data indicate that students exhibit improved use of the reasoning patterns and processes of science when engaged in the design and evaluation of their own experiments. Implications of the outcome of the research include an examination of existing learning cycle curricula with respect to the assertions of the learning model. Revisions in some of those curricula may be warranted.

STUDENT SCIENCE KNOWLEDGE RELATED TO ENVIRONMENTAL PROBLEMS: AN ANALYSIS OF THREE STUDIES

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This study reports on the combined results of three previous studies (Brody, Chipman & Marion, 1989; Brody & Koch, 1990; Brody, 1990), each designed to assess fourth, eighth and eleventh grade students' understanding of natural and social science concepts related to current environmental problems. All studies were conducted by graduate student research teams under the direction of the author and embody similar strategies and assumptions. The total sample of public school students (n = 476) in forty one (41) Maine schools were interviewed on a variety of concept principles considered critical to a full understanding of three environmental problems. Concepts related to the environmental problems included; geography, geology, physical and chemical factors, ecology and natural resources. Research assertions were summarized in generalized correct concepts statements indicating the extent of current student scientific knowledge. Common misconceptions were also noted. This analysis considers student understanding as an integrated set of clusters of concepts related to the environment. This reflects a complex, integrated and multidisciplinary conception of a natural phenomena. Human constructivism, meaningful learning theory and principles related to the relevance of student schema in the design of curriculum and instructional strategies guide this work. The results of this meta-analysis have implications for teaching about current environmental problems and the design of science education curriculum materials based upon student knowledge. This information can guide teaching strategies and thus help learners gain an appreciation for the complex and multidisciplinary nature of science, technology and society and how they affect the environment.

THE EFFECTS OF TEXT COMPOSITION ON STUDENT ORGANIZATION OF SCIENCE CONTENT USING A HIERARCHIAL-NETWORK MODEL OF ANALYSIS

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Modern constructivist theories of text comprehension assume that the reader imposes unique interpretations due to the particular, or idiosyncratic, set of schemata (organizing frameworks) they bring to the reading task. This process, however, is also influenced by the test organization, but there is little research on the relative contribution of text-driven variables compared to constructivist activity of the learner during perception and encoding of content. This study examined the effects of two different science test structures on the organization of information reported by respondents after reading the experimental material. In addition, two content areas were examined, biology and chemistry. The responses were analyzed using our standard hierarchical-network (H-N) system. This allows us to determine how the amount of hierarchically ordered and interrelated information unites in the respondent's interpretations of a set of paragraphs. Fifty-two students, from four secondary school classes of an inner city school, who had been randomly assigned to treatments, completed the study. There were four treatment groups (receiving texts in either biology or chemistry with two levels of organization); each group received a reading task consisting of five paragraphs, each printed at the top of a response form that asked the respondent to list in the spaces provided what they concluded was the most general idea, next general idea, and the least general idea in the paragraph. The H-N analysis yielded a set of numerical coefficient for each paragraph indicating the relative weight, or modal organizational significance, of the paragraph relative to all other paragraphs in the respondent's network of ideas. The mean value for the set of coefficients was used as an overall indicator of network organization in the responses as is our procedure in the H-N analysis. The major findings are as follows: (1) There is a greater difference in mean coefficients for texts with different content (biology vs. chemistry) than for variations in structure for the same content ($p < 0.05$); (2) when the same content (whether biology or chemistry) but different structure is present to the reader, the variances of the rank-ordered column coefficients are consistently greater for responses to the "less organized" form of the same content than for the "more organized" form; (3) there is a shift in the information selected toward sentences with what we categorized as "more familiar content" when the text is less ordered. This is consistent with constructivist interpretations that the students will mobilize schemata and focus on more familiar material as a way of assimilating it within existing knowledge; (4) the result are very similar for respondents receiving the biology text compared to those receiving the chemistry text.

EFFECTS OF AN ENVIRONMENTAL EDUCATION-RELATED STS APPROACH ON THE COGNITIVE STRUCTURES OF PRESERVICE SCIENCE TEACHERS

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Pre- and post-course concept maps of expressions selected from this issue of global climate were assigned in the subject domain of science, technology, or society. Maps were analyzed for the frequencies of propositions, frequencies of propositions within subject domain, frequency of propositions across subject domains, and proposition strength scores. Data were compared to credit hours in each subject domain and the students' final examination scores. The study found that subjects tended to identify relationships between words of the same content domain more frequently than relationships between words of different content domains. The number and average scores of propositions from the concept maps which connected words from the technology domain were correlated with the number of science credits completed prior to the course and the scores of the final course examination. The mean average score of the propositions of the technology content domain for the second mapping activity was significantly higher than the same proposition types from the first mapping activity. There was a trend for the number of propositions identified in the science and the society content domains to increase from the first to the second mapping activity. There was no evidence that the subjects tended to make more connections between words from different content domains after completion of the course.

IMPLEMENTING TECHNOLOGY WITHIN THE CURRICULUM: A CASE STUDY INVOLVING SIX SECONDARY SCHOOLS

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The purpose of the study was to evaluate the effectiveness of the implementation of technology within the curriculum of six secondary schools. Technology has the potential to become an important subject in the curriculum. However, how the subject is to be covered in the school curriculum is a source of great debate: one approach is that dominated by craft teachers, a second is an approach focusing on hi-tech advances such as computers and electronics. A third approach presents technology as an engineering course at the secondary level, while a fourth views technology as subset of science. In this study each of the six high schools chose to implement technology in its own way and this research considered the effectiveness of the implementation process in terms of (a) the intended curriculum which related to the way technology is presented by the written materials, the syllabus and the teaching foci; (b) the implemented curriculum which related to the way the schools incorporate technology into their programs; (c) the perceived curriculum which related to what the researchers, as external observers, consider the way that technology is incorporated into the programs; and (d) the achieved curriculum which is the students' knowledge and attitudes gains as a result of the implementation. A number of general conclusions can be made based on this case study of technology implementation. First, the different perceptions of technology have been associated with different intended curricula. These differences are related to the ways in which funds have been distributed and spent. Second, all schools followed their intended curriculum with some modification but progress was slower than expected. Thirdly, in schools where the implementation process focused on people, rather than equipment, staff were generally happy with their level of funding. Schools which relied upon equipment for their implementation experienced delays associated with the equipment which, in some cases, have prevented particular projects from getting underway. Fourth, the data from student questionnaires revealed that, aside from the usual decline in interest over the years, students' attitudes and understanding about technology are positive and have improved, suggesting that the technology implementation in these schools has had a measurable impact on students.

TEACHING TECHNOLOGY AS A DESIGN PROCESS: AN EVALUATION OF CURRICULUM MATERIALS FOR MIDDLE SCHOOL SCIENCE

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This paper described the evaluation of three curriculum modules to teach technology. Since technology was explicitly incorporated into the Science and Technology component of the K-10 curriculum in Western Australia, there have been no clear guide-lines to teachers about how the introduction of technology might be achieved. The technology curriculum modules described in this paper represent the first attempt to formalize the study of technology in the elementary school in this state. Technology is presented as a design process, which follows a cycle involving problem identification and analysis, generation and evaluation of alternative solutions, planning and construction of models, trailing, modification and evaluation. The curriculum evaluation was designed to answer five questions. How appropriate and understandable to the classroom teacher is the presentation style of the technology modules? Are the sequence and selection of content and the teaching strategies appropriate for achieving the curriculum objectives? Is the suggested approach compatible with the likely resources available and teaching schedules of the typical elementary classroom? Are the curriculum materials effective in stimulating students' interest and understanding of technology and the technological process? Are the curriculum materials gender-inclusive? Both quantitative and qualitative methods were used to gather data in the evaluation. The results indicated that teachers found the materials successful for teaching technology using the design process, that the resources required are compatible with those available, and that the materials are gender-inclusive. Student's knowledge of technology and their general attitude toward technology have become more positive. Most importantly the success of the materials suggest that they could be used as a general model for teachers to develop curriculum materials using a technological problem-solving approach to science-related issues.

SCORING STUDENT-GENERATED CONCEPT MAPS IN INTRODUCTORY COLLEGE CHEMISTRY

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This study presents a quantitative method for scoring concept maps generated by students learning introductory college chemistry. Concept maps provide a visualization of cognitive structure. When a student draws a concept map for chemical reactions the result is a personification of the student's conceptual framework for understanding the concepts and propositions of chemical change. Developing a valid method for scoring student concept maps will enable educators to evaluate students' knowledge free of the bias and arbitrariness often associated with qualitative reviews. The scoring methodology presented in this study permits evaluation of the learning characteristics of students in chemistry. The concept map measures the amount of chemical information the student possesses, reasoning ability in chemistry and the presence of specific misconceptions of introductory and physical chemistry concepts. This research has demonstrated that the concept map category score for propositional validity reflects student reasoning ability in chemistry. The ratio of valid connecting lines to total number of connecting lines drawn (per strand) significantly correlated with formal reasoning ability in chemistry. The corresponding map category score for hierarchical structure reflects the amount of chemical information possessed by a student. Students who possess large amounts of information about chemistry position more vocabulary words within each hierarchical level than the student who demonstrates limited chemical knowledge. The data in this research also suggest the greater a student's understanding of introductory chemistry concepts the more strands s/he employs in mapping concepts and propositions related to chemical reactions. Low strand count reflected specific misconceptions about Avogadro's Number, the mole concept, and the Law of Conservation of Matter. This study documents a method for objectively measuring student heuristic processing in chemistry. One possible application of this study's findings is the utilization of concept map category scores to make informed decisions about instructional design. Educators in science may consult student concept map category scores to gain information about student understanding in a given domain. Effective educational programs which strive to remediate misconceptions about scientific knowledge may use this information to develop instructional strategies complementary to individual student learning traits. Utilizing category scores as a student diagnostic tool prior to curriculum development is appropriate for live, teacher-assisted classroom instruction as well as knowledge-based computer-assisted instruction.

THE EFFECT OF LEVEL OF INFORMATION AS PRESENTED BY DIFFERENT TECHNOLOGIES ON STUDENTS' UNDERSTANDING OF ACID, BASE, AND pH CONCEPTS

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This study investigated students' understanding of acid, base, and pH concepts before and after titrations using three technologies which each present the learner with a different level of information. The technologies included: chemical indicators, pH meters, and microcomputer-based laboratories (MBL). Our working hypothesis was that the level of information presented by the technology would influence the cognitive structure of the learner. We investigated both the change in the cognitive structure of the students' knowledge of acids, bases, and pH from pretreatment to posttreatment and the thought process in which the students engaged during the treatment activities. In this paper, we report on students' cognitive structures prior to and after interacting with these technologies. The 15 students in the study were in grade 11 and were completing a regular first-year chemistry course. Each group titrated a strong acid, a weak acid, and a polyprotoc acid with a strong base. Treatment group 1 used a chemical indicator to detect changes in pH, group 2 used a pH meter, and group 3 used a microcomputer. Verbal data and drawings obtained in clinical interviews were used to construct concept maps and to analyze their molecular concepts. Subconcepts, termed nodes, referenced three or more times were identified as critical nodes, i.e., essential to that students' understanding. Experts were also interviewed, and their concept maps were analyzed to identify critical nodes on their understanding of acids, bases, and pH. From our analysis, we drew three conclusions. First, microcomputer-based laboratory activities seem to help students construct more powerful and more meaningful chemical concepts. The posttreatment concept maps showed greater differentiation and integration of concepts. The microcomputer students expressed more acceptable subconcept nodes, linked those nodes with more acceptable propositions, and built more cross links between nodes. They also build their maps around more acceptable critical nodes, including several expert critical nodes. Although students still exhibited weaknesses in their understanding, their posttreatment knowledge of acids, bases, and pH was more detailed and more integrated than the knowledge of the other groups. Second, the microcomputer group had a higher error rate than the other groups. Students apparently construct more concepts using MBL, but directed teaching and class discussion is needed to counteract the formation of inappropriate concepts. Third, interview drawings indicate weaknesses in the students' understanding of molecular concepts of matter. Several students had weak or nonexistent molecular concepts, and some students did not change their molecular concepts during the study.

TRANSLATION OF REPRESENTATIONS OF THE STRUCTURE OF MATTER AND ITS RELATIONSHIP TO REASONING, GENDER, SPATIAL REASONING, AND SPECIFIC PRIOR KNOWLEDGE

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The purpose of this study was to characterize high school chemistry students' ability to make translations between three representations of the structure of matter, and to determine the degree to which the students' ability to make these translations is related to reasoning ability, spatial reasoning ability, gender, and specific knowledge of the representations. Translation between formula, electron configuration, and ball-and-stick model representations of matter were chosen for study because of their promise for adding to knowledge of students' conceptual ecology, and because they may be of practical use for teaching and evaluation in chemistry classrooms. Representations have the characteristic that they embed selected details of the relevant concept or principle, but permit other details to "fade". As one example, the chemical formula for water, H_2O, explicitly conveys the identity of the constituent elements and their ratios but does not explicitly convey the bond angle or whether the bonds are single or double. On the other hand, the ball-and-stick model of water explicitly conveys the bond angle and bond orders, but does not emphasize the ratio of the elements. Translation between representations is an information processing task, requiring understanding of the underlying concept to the extent that the individual can interpret the information provided by the initial representation and infer the details required to construct the target representation. In this study the use of the translations of representations as an indicator of understanding of chemical concepts if developed in terms of (1) its relationship to four variables associated with achievement in chemistry, (2) specific representation error types, and (3) its utility in revealing details of students conceptions and concept formation. Translation of representation performance was measured by administering, audio recording, transcribing, and scoring individual, task-based, think-aloud interviews. The associated interview schedule was entitled Translation of Representations -- Structure of Matter [TOR-SOM]. Reasoning ability was measured by the Group Assessment of Logical Thinking -- short form (GALT-s), spatial reasoning ability by the Spatial Reasoning subtest of the Differential Abilities Test subtest (SR-DAT), and prior knowledge of the representations by a test developed by the researcher (Knowledge of Representations -- Structure of Matter, KOR-SOM). When each of the hypothetical correlates were regressed on TOR-SOM individually, results indicated the KOR-SOM and GALT-s but not gender or SR-DAT were statistically significant (alpha = .05). The two-predictor model accounts for 28% of the variance in the TOR-SOM scores. Representation error types are described and exemplified.

ASSESSMENT OF SCIENCE LAB SKILLS AT THE HIGH SCHOOL LEVEL

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This discussion is about an on-going research effort to assess the level of the science lab skills of students in high school science courses. This research is an attempt to develop "authentic" assessment for some of the elusive outcomes of the science laboratory. Most of the work in this area has been at the elementary and middle levels of schooling. Relevant efforts of the First International Science Study, National Assessment of Educational Progress, Second International Science Study and the Assessment of the Performance Unit (in the United Kingdom) were examined for useful ideas. The Israeli Biology Lab Practical Examination and the Ontario Assessment Instrument Pool (OAIP) were excellent resources for our work. We have produced a set of 6 tasks per each science area; biology, chemistry, and physics. Each task is composed of two parts, each administered within a 45 minute class period. Part A provided an introduction and a brief statement of a problem for which the student was to design an investigation. This format of science laboratory work in the USA is believed to be under-utilized. In Part B, the students conduct the investigation -- with a set of measurements, and conclusions in test booklets. These booklets were scored by modifications of those used in Israel and in Ontario. It is expected that these tasks could be used in a number of ways, but the most obvious is program education. As there is a set of 6 tasks in each content area (each requiring a 2 person administration) to use them for all student assessment would probably produce a "testing burden". At the end of a course or the entire high school program, each student could respond to a sample of these tasks. It is quite clear that a test has an effect on what is taught. If valid, reliable and usable tests that assess lab skills can be provided it is possible that school science programs will become more than textbook and verification labs.

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